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Evaluation of Hydrologic Data Collected at the North Penn Area 12 Superfund Site, Montgomery County, Pennsylvania

by Lisa A. Senior, Kevin E. Grazul, and Charles R. Wood

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CONTENTS

ILLUSTRATIONS

Plate

[in pocket]

Figures

TABLES

CONVERSION FACTORS, ABBREVIATED WATER-QUALITY UNITS, AND VERTICAL DATUM

Multiply	By	To obtain
	Length	
inch (in.)	2.54	centimeter
foot (ft)	0.3048	meter
mile (mi)	1.609	kilometer
	Area	
acre	0.4047	hectare
	Volume	
gallon (gal)	3.785	liter
	Flow rate	
gallon per minute (gal/min)	0.06309	liter per second
	Specific capacity	
gallon per minute per foot [(gal/min)/ft]	0.2070	liter per second per meter
	Temperature	
degree Celsius (°C)	°F = 9/5 °C + 32	degree Fahrenheit

Abbreviated water-quality units used in report:

mg/L, milligrams per liter

µS/cm, microsiemens per centimeter at 25 degrees Celsius

Sea level: In this report, “sea level” refers to the National Geodetic Vertical Datum of 1929—a geodetic datum derived from a general adjustment of the first-order level nets of the United States and Canada, formerly called Sea Level Datum of 1929.

EVALUATION OF HYDROLOGIC DATA COLLECTED AT THE NORTH PENN AREA 12 SUPERFUND SITE, MONTGOMERY COUNTY, PENNSYLVANIA

By Lisa A. Senior, Kevin E. Grazul, and Charles R. Wood

ABSTRACT

The North Penn Area 12 Superfund Site is underlain by the Lockatong Formation, which consists of interbedded gray to black siltstone and shale. The beds of the Lockatong Formation strike northeast and dip about 10° to 20° to the northwest in the vicinity of the site. Ground water moves through fractures that are nearly vertical and horizontal in the shale and siltstone. Permeability and storage are very low.

Borehole-geophysical logs were obtained from eight wells to determine the location of fractures, water-producing and water-receiving intervals, and intervals of borehole flow. The logs also were used to quantify fluid movement in the borehole, to characterize the lithology, and to obtain data on well construction. The logs indicate fractures at depths less than 100 feet are more frequent and generally are more productive than fractures at depths greater than 100 feet. The fluid resistivity of water in shallow intervals usually was greater than that in deeper intervals. The rate and direction of fluid movement under nonpumping conditions differs in the boreholes logged. In the northwest part of the site, no vertical flow was detected in three wells and very small amounts of flow were measured in two wells. In the southwest part of the site, downward flow was measured in two wells.

Aquifer-isolation tests in three wells provided information on hydraulic heads and specific capacities in discrete vertical intervals and allowed collection of water samples from discrete water-bearing intervals.

Natural annual fluctuations of water levels in 11 wells ranged from 11.4 to 28.3 feet. Seven of the 11 wells have very similar water-level hydrographs. The four southernmost wells on the site show rises in water levels after precipitation much sooner than the other seven wells. Two other wells show daily fluctuations caused by pumping. A potentiometric-surface map of the site and vicinity was prepared from water-level measurements made in late July 1995. The map can be used to determine the approximate direction of ground-water flow.

INTRODUCTION

Chlorinated organic solvents including trichloroethylene (TCE) and trichlorofluorocarbon (Freon-113 or CFC-13) have been detected in ground water from wells at and near the North Penn Area 12 Superfund Site in Worcester Township, Montgomery County, Pa. (fig. l) (CH2M Hill, 1994). Wells at the 50-acre site include 3 inactive production wells and 12 monitor wells. Offsite, solvents were detected in water from an abandoned well at Nike Park, an active production well at the Center Point Training Center (Rehab Center) (fig. 2), and some domestic wells north of the site.

In order to remediate the site, the U.S. Environmental Protection Agency (USEPA) needs information on the hydrologic, geologic, and hydraulic characteristics of the site. The U.S. Geological Survey (USGS), in cooperation with the USEPA, conducted a hydrogeological assessment of the site and the surrounding area. The data collected by the USGS in 1995 and 1996 will be used to help define the geology, distribution of fractures in the rocks, directions of ground-water flow, and probable patterns of contaminant migration at and in the immediate vicinity of the site.

Purpose and Scope

This report presents and evaluates results of packer tests of 3 boreholes, borehole-geophysical logs obtained from 8 boreholes, water-level monitoring at 14 wells, and potentiometric-surface mapping at the North Penn Area 12 Superfund Site. Caliper, natural-gamma, single-point-resistance, fluid-temperature, fluid-resistivity, fluid-velocity (heat-pulse flowmeter), and electromagnetic-induction (EM) logs were obtained. A borehole television survey also was done in each borehole. Specific objectives of borehole-geophysical logging were to (1) locate subsurface fractures; (2) identify, where possible, important water-bearing fractures; (3) identify intervals of potential vertical borehole fluid flow; (4) measure directions and rates of vertical flow in the borehole; and (5) determine construction characteristics of wells, where unknown. This report provides a summary of findings for each borehole, including the depth of openings, most of which are fractures and possible water-bearing zones, and depth and quantification of vertical borehole flow, if measurable. Results of geophysical logging conducted by the USGS will be used to help define the geology, ground-water-flow directions, fracture distribution, and contaminant-migration patterns in the immediate vicinity of the site. The report also provides a summary of findings for each aquifer-isolation test, including the depths of each packer setting, pre- and post-pumping water levels in each isolated interval, pumping rates, and measured water-quality constituents. Specific capacities for each interval are calculated. In addition, specific capacities determined from pumping open boreholes during geophysical logging also are presented. Results of aquifer-isolation tests conducted by the USGS will be used to help define the permeabilities of discrete intervals in the aquifer and the vertical distribution of contaminants in the aquifer at the site. Water-level monitoring helps to identify which wells penetrate the same water-bearing zones, because wells that penetrate the same zones tend to have similar hydrographs. The potentiometric-surface map can be used to understand the probable direction of contaminant movement. Data for all wells inventoried are given in the appendix, and locations are shown on figure 1. A larger-scale map (fig. 2) shows the locations of wells within and immediately adjacent to the site boundary.

Geohydrologic Setting

The North Penn Area 12 Site is in the Triassic Lowlands Section of the Piedmont Physiographic Province. The site is underlain by the Lockatong Formation (pl. 1) of the Newark Supergroup (Lyttle and Epstein, 1987). The Lockatong Formation consists of interbedded gray to black siltstone and shale. Interbedded 10- to 270-ft-thick reddish brown, sandy siltstone units mapped previously as the Brunswick Formation (Longwill and Wood, 1965) crop out within 0.25 mi to the northwest and southeast of the site. Rocks of the Lockatong Formation contain detrital cycles of gray to black calcareous shale and siltstone with some pyrite and chemical cycles of gray to black dolomitic siltstone and marlstone with lenses of pyritic limestone overlain by massive gray to red siltstone with analcime (Lyttle and Epstein, 1987). The beds of the Lockatong Formation strike northeast and dip about 10° to 20° to the northwest in the vicinity of the site.

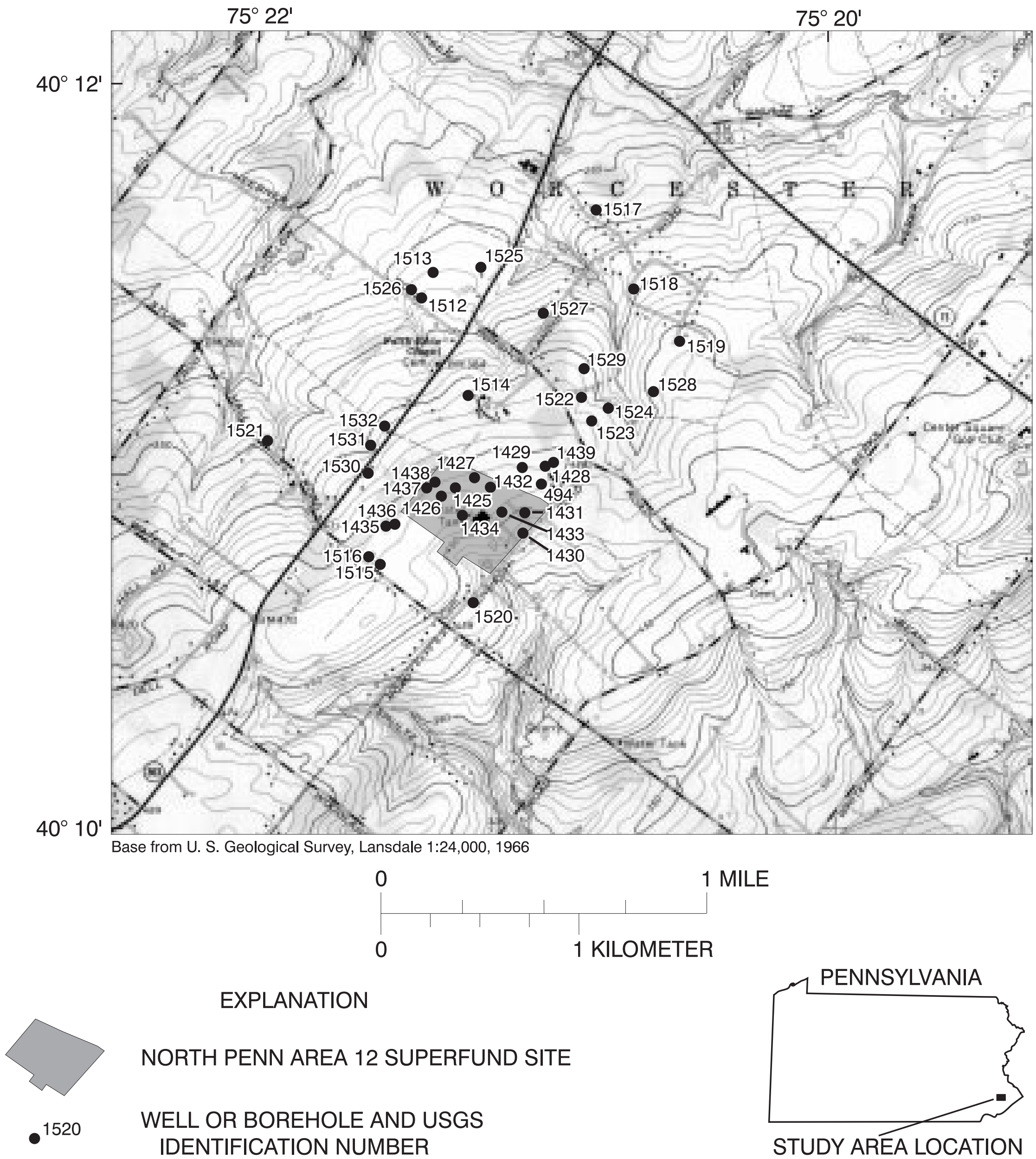

Figure 1. North Penn Area 12 Superfund Site showing locations of all wells used in the study, Worcester Township, Montgomery County, Pa.

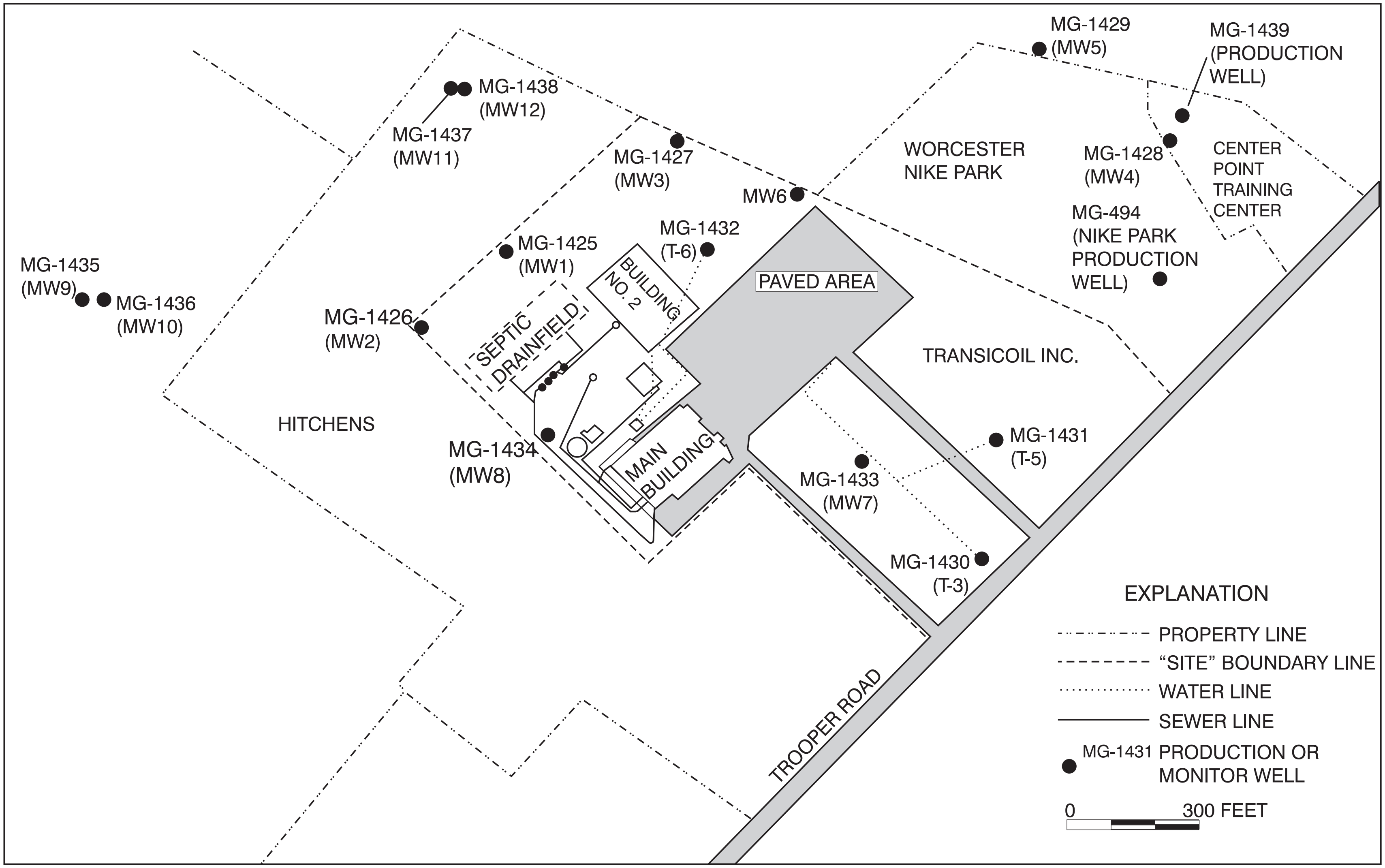

Figure 2. Well locations at the North Penn Area 12 Superfund Site, Worcester Township, Montgomery County, Pa. (Modified from CH2M Hill, 1994, figs. 4-5.)

Ground water moves through fractures that are nearly vertical and horizontal in the shale and siltstone. Primary porosity is very low or nonexistent. Permeability and storage are very low. Ground water in the Lockatong Formation may be under confined, unconfined (water table), and (or) perched conditions. Ground water in the upper part of the aquifer generally is under unconfined conditions; ground water in the deeper part of the aquifer may be confined or partially confined, resulting in local artesian conditions (Sloto and Schreffler, 1994, p. 19 and 22-24).

STUDY METHODS

Geophysical Logging

Borehole-geophysical logs were obtained from monitor wells MG-1425, MG-1426, MG-1427, and MG-1438 (MW-1, MW-2, MW-3, and MW-12, respectively); production wells MG-1430, MG-1431, and MG-1432 (T-3, T-5, and T-6, respectively); and MG-1439 (Rehab Center well) (table 1). The four monitor wells logged had not been pumped for several years, except for MG-1438, which had been redrilled (reamed several feet into bentonite cement grout at bottom) just before logging. Three of the production wells (MG-1430, MG-1431, and MG-1432) were inactive and had not been pumped for at least 1 year; pumps in these wells were removed a few days prior to logging. The Rehab Center well (MG-1439) is an active supply well; the pump in this well was removed temporarily about 12 hours prior to logging. Some well-construction information was available for monitor wells MG-1425, MG-1426, MG-1427, and MG-1438 and for production well MG-1432; total depths were known for MG-1430 and MG-1431; and no data were available for the Rehab Center well (MG-1439).

Table 1. *Boreholes logged by the U.S. Geological Survey at the North Penn Area 12 Superfund Site, Worcester Township, Montgomery County, Pa., February 1995*

[C, caliper log; F, fluid-resistivity log; G, natural-gamma log; M, electromagnetic-induction log; R, single-point-resistance log; T, fluid-temperature log; V, heat-pulse-flowmeter measurement]

U.S. Geological Survey well number	Site well number	Geophysical logs[1]
MG-1425	MW-1	C, F, G, M, R, T, V
MG-1426	MW-2	C, F, G, M, R, T, V
MG-1427	MW-3	C, F, G, M, R, T, V
MG-1428	MW-4	
MG-1430	T-3	C, F, G, M, R, T, V
MG-1431	T-5	C, F, G, M, R, T, V
MG-1432	T-6	C, F, G, M, T, V
MG-1438	MW-12	C, F, G, R, T, V
MG-1439	Rehab Center	C, F, G, M, R, T, V

[1] A videotape of each well was made using borehole television.

The geophysical tools run in each borehole included caliper, natural-gamma, single-point-resistance, fluid-temperature, fluid-resistivity, fluid-velocity (heat-pulse flowmeter), and electromagnetic induction (EM) (table 1). A borehole television survey was done in each borehole. The single-point-resistance tool was not run in MG-1432, and the EM tool was not run in MG-1438. The logging was conducted from February 21-27, 1995. Because air temperatures in February 1995 were too cold to permit brine tracing, borehole fluid flow was measured by the use of the heat-pulse flowmeter only. A borehole television survey only was done in MG-1428 (MW-4). Well MG-494 at Nike Park was not logged because of debris in the borehole.

Information provided by geophysical logging and borehole television surveys includes location of fractures and water-producing and water-receiving intervals and intervals of vertical borehole flow (caliper, fluid-resistivity, and fluid-temperature logs and borehole television survey), quantification of vertical fluid movement within the borehole (heat-pulse flowmeter logs), lithologic characterization (natural-gamma and single-point-resistance logs), and data on well construction (caliper and EM logs).

Caliper logs provide a continuous record of average borehole diameter, which is related to fractures, lithology, and drilling technique. Caliper logs are used to help correlate lithostratigraphy, identify fractures and possible water-bearing openings, and qualitatively correct other geophysical logs for changes in borehole diameter. Correlation of caliper logs with single-point-resistance, fluid-resistivity, and fluid-temperature logs is used to identify fractures, water-producing and water-receiving intervals, and intervals of vertical borehole flow.

Single-point-resistance logs record the electrical resistance between the borehole and an electrical ground at land surface. In general, resistance increases with grain size and decreases with borehole diameter, density of water-bearing fractures, and increasing dissolved-solids concentration of borehole fluid. A fluid-filled borehole is required for single-point-resistance logs, and they are obtained only from the saturated part of the formation below the casing. Single-point-resistance logs are used to correlate lithostratigraphy and may help to identify the location of water-bearing intervals.

EM logs record the electrical conductivity of the formation surrounding the borehole. An alternating electric current is transmitted, which induces currents in conductive rocks around the borehole that in turn set up secondary magnetic currents that induce a voltage in the receiving coil of the logging tool. Major factors that affect EM logs in sedimentary aquifers are dissolved-solids concentration in ground water in the formation (conductivity increases with increases in dissolved-solids concentration) and the conductivity of aquifer materials (clay generally is more conductive than sand) (Williams, 1994). Thus, EM logs can be used with natural-gamma and other logs to correlate lithostratigraphy and possibly to identify intervals of ground water having relatively high dissolved-solids concentration. EM logs also can be used to verify depth of casing because metal casing has very high conductivity (low resistivity) compared to most aquifer materials.

Natural-gamma logs, also called gamma-ray logs, record the natural-gamma radiation emitted from rocks penetrated by the borehole. Gamma radiation can be measured through casing, but the gamma response is dampened. Uranium-238 and thorium-232 and their decay products and potassium-40 are the most common emitters of natural-gamma radiation. These radioactive elements may be concentrated in clay by adsorption, precipitation, and ion exchange; accordingly, fine-grained sediments (siltstone units) usually emit more gamma radiation than do quartz sand rocks (sandstone). Extremely elevated gamma activity associated with thin intervals were noted in some of the deeper holes at the site, and these intervals can be used as marker beds for stratigraphic correlation.

Fluid-resistivity logs record the electrical resistivity of fluid in the borehole. Resistivity is the reciprocal of fluid conductivity, and fluid-resistivity logs reflect changes in the dissolved-solids concentration of the borehole fluid. Fluid-resistivity logs are used to identify water-producing and water-receiving intervals and to determine intervals of vertical borehole flow. Water-producing and water-receiving intervals usually are identified by sharp changes in resistivity, and intervals of borehole flow are identified by a low resistivity gradient between water-producing and water-receiving intervals.

Fluid-temperature logs provide a continuous record of the temperature of the fluid in the borehole. Temperature logs are used to identify water-producing and water-receiving intervals and to determine intervals of vertical borehole flow. Intervals of vertical borehole flow are identified by little or no temperature gradient. Temperature logs from wells with little or no borehole flow commonly show an increase in fluid temperature with depth as a function of the geothermal gradient in the lower part of the borehole.

In selected boreholes, the direction and rate of borehole-fluid movement was determined by the use of a heat-pulse flowmeter. A diverter channels all borehole flow through the flowmeter. The heat-pulse flowmeter operates by slightly heating a small volume of water between two sensitive thermistors (heat sensors). When a peak temperature is recorded by one of the thermistors, the direction and rate of vertical borehole flow is computed. The range of flow measurement is about 0.01-1.0 gal / min in a 2- to 8-in.-diameter borehole and reflects only the vertical component of flow. Generally, the flowmeter was placed at depths between suspected water-producing or water-receiving fractures. Both water-producing and water-receiving intervals are indirectly indicated by fluid-velocity data.

The heat-pulse flowmeter was used under both nonpumping and pumping conditions. For wells MG-1425, MG-1426, and MG-1432, in which the heat-pulse flowmeter data indicated very low or no vertical borehole flow, a pump was lowered a few feet below the water level in the well, and the well was pumped at a rate of 1 gal / min or less. During pumping, the borehole-flow rate was measured again at the same depths as before pumping. The difference in the flow rate between nonpumping and pumping conditions identifies intervals with the greatest fluid production and indicates the relative production rates of these intervals.

Aquifer-Isolation Tests

Most ground-water flow and contaminant movement at the site occurs in distinct water-bearing intervals (fractures) rather than through primary openings in the bedrock. The hydraulic and chemical characteristics of each discrete water-bearing interval can differ. These differences can be characterized by isolating each water-bearing interval in a borehole with straddle packers so that its properties can be determined separately from the other intervals in the borehole.

The objectives of the aquifer-isolation tests were to (1) provide information on water levels and specific capacities in discrete vertical intervals, and (2) allow collection of water samples from discrete water-bearing intervals so that the vertical extent of contamination in each borehole could be characterized.

Aquifer-isolation tests were done in monitor wells MG-1425 and MG-1426 and production well MG-1431 in March 1995 (fig. 2) (table 2). Packers were set to isolate selected water-bearing intervals; the number and depths of intervals to be tested in each borehole were based on an analysis of the borehole-geophysical logs. A straddle packer isolates three intervals and a single packer isolates two intervals in a borehole. The rubber bladder of each packer is about 2 ft in length, such that when inflated, each packer acts as a plug sealing 2 ft of the borehole between two intervals. Water levels in each isolated interval were measured with electric tapes before and after packer inflation. Water levels also were measured with pressure transducers during pumping; drawdowns were recorded at a change of 0.1 ft in water level rather than at fixed times. Pumping duration for each aquifer-isolation test was approximately 1 hour, at rates ranging from about 0.5 to 6 gal / min.

Table 2. *Boreholes pumped by the U.S. Geological Survey at the North Penn Area 12 Superfund Site, Worcester Township, Montgomery County, Pa.*

[--, not tested]

U.S. Geological Survey well number	Site well number	Date borehole pumped with packers	Date borehole pumped without packers
MG-1425	MW-1	3-16-95	2-27-95
MG-1426	MW-2	3-14-95	2-27-95
MG-1431	T-5	3-17-95 3-20-95	--
MG-1432	T-6	--	2-23-95

Specific capacities (ratio of pumping rate to drawdown) for each isolated interval were calculated. Additional data on specific capacities of open boreholes determined from pumping rates and drawdowns during pumping for flowmeter tests done in February 1995 also are presented.

The pH, specific conductance, turbidity, dissolved oxygen, and temperature of the water discharged from the boreholes were measured at various times during pumping with a multiparameter meter provided and calibrated by a USEPA contractor. When these physical and chemical properties stabilized, water samples were collected by the contractors.

ANALYSIS OF BOREHOLE-GEOPHYSICAL LOGS AND AQUIFER-ISOLATION TESTS

The locations of boreholes logged are shown on figure 2. The reference measuring point for all geophysical logs was the top of casing or the top of the concrete platform (pad) for wells in pits (MG-1430 and MG-1435) (table 3). Depths are reported in feet below top of casing or below top of pad. Geophysical-log depths may be corrected to a land-surface datum by subtracting the height of the top of casing or top of pad above land surface (table 3). Depths of wells and casing lengths indicated by geophysical logs and water levels at the time of logging are given in table 3.

***Table 3.** Well depth, casing length, and depth to water for boreholes logged by the U.S. Geological Survey at the North Penn Area 12 Superfund Site, Worcester Township, Montgomery County, Pa., February 1995*

[ft, feet; TP, top of pad; TC, top of casing]

U.S. Geological Survey well number	Site well number	Measuring point	Height of measuring point above land surface (ft)	Depth of well below measuring point (ft)	Length of casing below measuring point (ft)	Depth to water below measuring point (ft)	Date water level measured
MG-1425	MW-1	TC	2.4	123	23	63.98	2-24-95
MG-1426	MW-2	TC	2.4	112	25	68.33	2-24-95
MG-1427	MW-3	TC	1.7	161	23	59.38	2-23-95
MG-1428	MW-4	TC	1.9	112	49	49.00	2-25-95
MG-1430	T-3	TP	[1] .7	305	45	18.46	2-26-95
MG-1431	T-5	TP	[2] .0	133	21	24.49	2-25-95
MG-1432	T-6	TC	.5	905	21	64.35	2-21-95
MG-1438	MW-12	TC	1.4	214	120	62.75	2-22-95
MG-1439	Rehab Center	TC	1.7	498	29	50.21	2-25-95

[1] Top of pad; top of casing is 2.9 ft below land surface.
[2] Top of pad; top of casing is 3.4 ft below land surface.

MG-1425 (MW-1)

The caliper log (fig. 3) shows the total depth of the borehole is 123 ft below top of casing and it is cased with 6-in.-diameter casing to 23 ft below top of casing. The depth to water was 63.98 ft below top of casing at the time of logging. The caliper log shows openings above the water level at 25-27, 30-32, and 39-41 ft below top of casing. Below the water level, the caliper log shows fractures at 63, 71-73, 78, 104, and 117-120 ft below top of casing. The borehole television survey shows the orientation of most major fractures is vertical or subvertical, including fractures at 25-27, 30-32, 39-41, and 71-73 ft below top of casing. Numerous other minor vertical and horizontal fractures can be seen along the open interval, as well as calcite veins and alternating gray and red siltstone. Water at the bottom 0.5 ft of the borehole was cloudy. The television survey also showed the borehole walls were wet from below the casing down to the water level, suggesting slow seepage into the borehole from intervals above the water table.

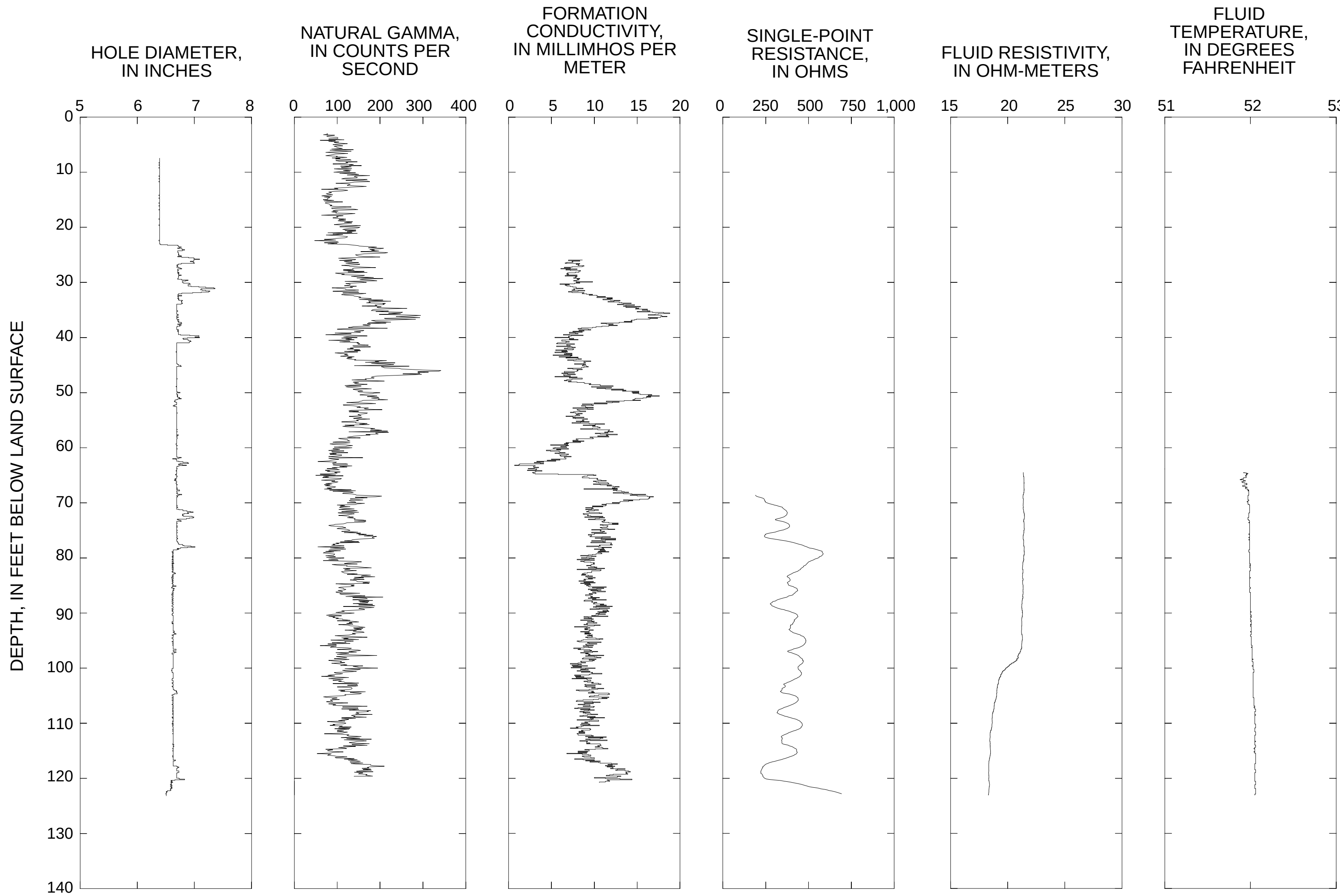

Figure 3. Geophysical logs for borehole MG-1425 (MW-1), North Penn Area 12 Superfund Site, Worcester Township, Montgomery County, Pa.

The fluid-resistivity log (fig. 3) shows a change in slope at 97-99 ft below top of casing. The fluid-temperature log (fig. 3) shows almost no gradient from 64 to 97 ft below top of casing, indicating a potential interval of borehole flow, and a minor change in slope (temperature increase) below 99 ft below top of casing. The heat-pulse flowmeter was used to test for vertical borehole fluid movement under nonpumping conditions at several depths (table 4). Flow near the lower limit of detection was observed at 75 ft below top of casing (table 4). Under pumping conditions (at a rate of about 0.64 gal / min), a fracture at 78 ft below top of casing produced most of the fluid; at 80 ft below top of casing, flow was near the lower limit of detection. At depths greater than 80 ft below top of casing, the rate of flow, if present, was too small to measure. The fracture at 78 ft below top of casing appears to be the most productive in the borehole.

Table 4. *Summary of heat-pulse-flowmeter measurements under nonpumping and pumping conditions in well MG-1425 (MW-1), North Penn Area 12 Superfund Site, Worcester Township, Montgomery County, Pa.*

[ft, feet; gal/min, gallons per minute; ND, not detected; --, not tested]

Depth of heat-pulse release (ft below top of casing)	Nonpumping conditions[1]		Pumping conditions[2]	
	Flow rate (gal/min)	Flow direction	Flow rate (gal/min)	Flow direction
66	ND		--	
69.5	ND		--	
71.5	--		[3] 0.197	up
75	0.012	down	.494	up
80	ND		.011	up
95	ND		--	
110	ND		--	

[1] February 24, 1995, depth to water was 63.98 ft below top of casing.

[2] February 27, 1995, depth to water was 63.87 ft below top of casing before pumping; pumping rate was about 0.64 gal/min; pump set at 70 ft below top of casing.

[3] Measured flow rate may be less than actual because heat-pulse flowmeter was in a fractured portion of the well, and some flow may have bypassed the diverter.

Aquifer-isolation tests were conducted on March 15-16, 1995; depth to water in the open borehole was 61.48 ft below top of casing. A straddle packer was set in the borehole. The initial setup on March 15, 1995, in which the packer isolated intervals above 73 ft below top of casing, between 75 and 81 ft below top of casing, and below 83 ft below top of casing, showed very little difference in prepumping levels 20 minutes after inflation. The lack of head difference between intervals suggests they are hydraulically connected outside the borehole. Therefore, the packer was lowered about 20 ft to isolate intervals above 93 ft below top of casing (upper interval), 95 to 102 ft below top of casing (isolated or middle interval), and below 104 ft below top of casing (lower interval). Water levels stabilized about 15 minutes after packer inflation. The water level in the upper interval was higher than in the middle or lower interval (table 5).

During the first test, the isolated interval between the packers (95-102 ft below top of casing) was pumped. When the isolated interval was pumped, drawdown was observed in all three intervals (fig. 4, table 5). However, the drawdown in the upper interval was less than in the isolated and lower interval. The final water level in the lower interval was below the pressure transducer in the interval, and, therefore, drawdown was measured with an electric tape. If the packers effectively isolated the intervals inside the borehole, the observed drawdowns show that the intervals are connected outside the borehole.

During the second test, the pump was placed in the upper interval, which was open to the fractures at 63, 71-73, and 78 ft below top of casing. As in the first test, drawdown was observed in all three intervals (fig. 4, table 5). The drawdowns in the middle and lower intervals were similar in magnitude but less than

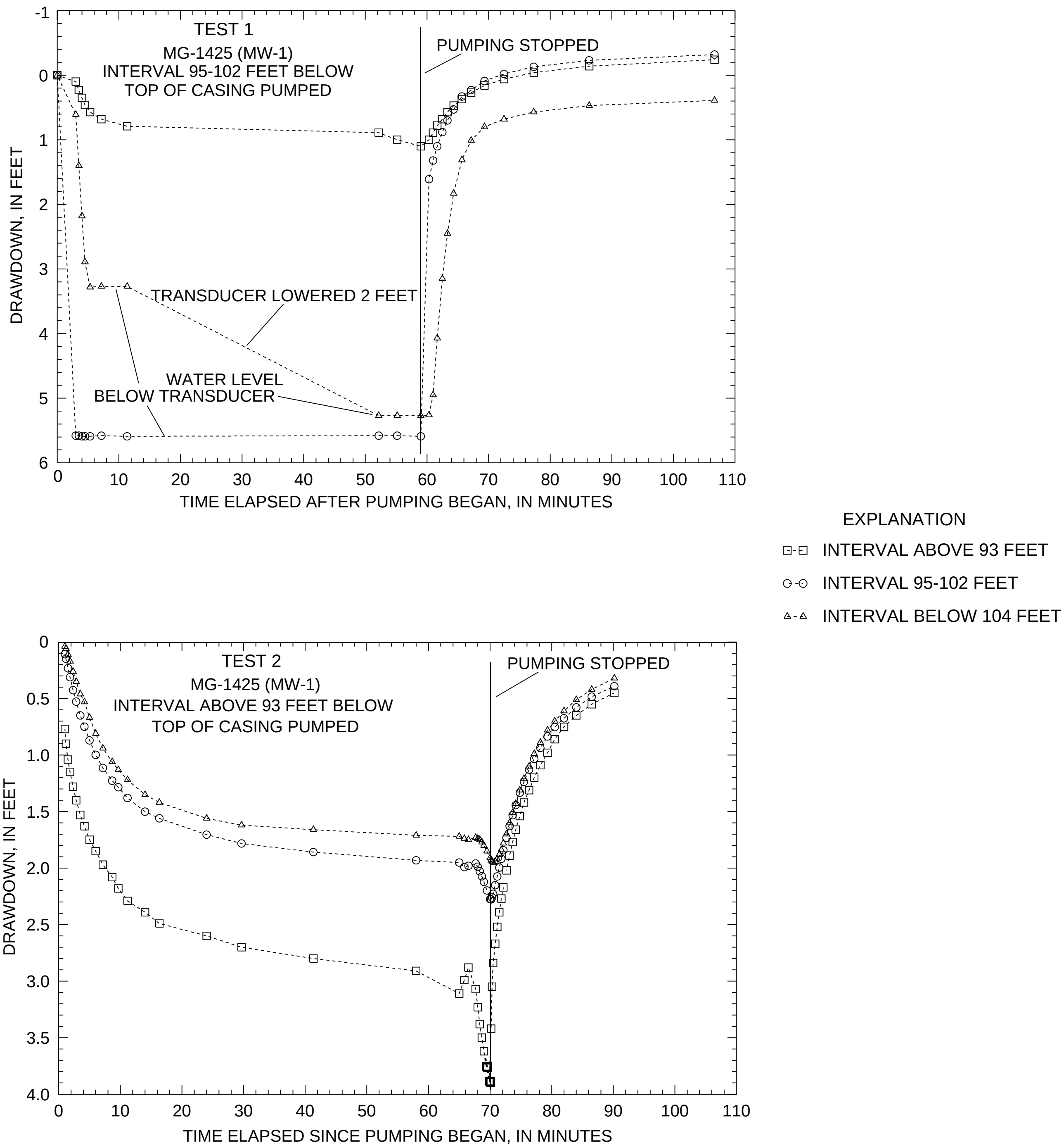

Figure 4. Drawdown as a function of time in three intervals of borehole MG-1425 (MW-1) pumped with packers in place at the North Penn Area 12 Superfund Site, Worcester Township, Montgomery County, Pa., March 16, 1995. [See table 5 for packer location and pumping rates.]

Table 5. *Depths, water levels, and specific capacity of intervals isolated by packers in borehole MG-1425 (MW-1) at the North Penn Area 12 Superfund Site, Worcester Township, Montgomery County, Pa.*

[ft, feet; gal/min, gallons per minute; (gal/min)/ft, gallons per minute per foot, --, not tested; >, greater than]

Depth of isolated interval in borehole (ft below top of casing)	Pre-pumping depth to water in interval[1] (ft below top of casing)	Depth to water in interval at end of test[2] (ft below top of casing)	Drawdown (ft)	Pumping rate (gal/min)	Pumping duration (minutes)	Specific capacity [(gal/min)/ft]
2-27-95 Test						
Open hole pumped	63.87	66.35	2.48	0.63	65	0.25
3-16-95 Test						
Open hole	61.48	--	--	--	--	--
		Test 1				
Above 93	61.73	62.63	1.10	--	--	--
95-102 (pumped)	61.86	68.65	[3] 6.79	.52	41	[4] .08
Below 104	61.83	>65.10	>5.27	--	--	--
		Test 2				
Above 93 (pumped)	61.40	64.35	2.95	.92	60	[5] .31
95-102	61.66	63.66	2.00	--	--	
Below 104	61.62	63.74	2.12	--	--	

[1] Packers inflated. Water levels reported after they stabilized.
[2] Depth to water reported at end of constant pumping rate before pump shut off.
[3] Drawdown measured with an electric tape.
[4] Reported specific capacity for interval greater than actual specific capacity because of contributions from other intervals.
[5] Calculated specific capacity for interval is greater than actual specific capacity because of contributions from other intervals.

in the upper pumped interval. These results show that the middle and lower intervals appear to act as one interval, which is connected outside the borehole and is not well connected to the upper interval. The upper interval has a greater specific capacity than the middle / lower interval, and these measurements are consistent with the heat-pulse-flowmeter measurements done on February 27, 1995, which showed that fractures in the upper interval produced most of the fluid when the open borehole was pumped.

The calculated specific capacities for the middle and upper intervals (table 5) in this borehole probably are greater than actual specific capacity for each interval because of contribution from other intervals. The specific capacity determined for the open borehole on February 27, 1995, is similar to that of the upper interval determined on March 16, 1995 (table 5).

The chemical and physical properties of the borehole discharge measured during the aquifer-isolation tests are given in table 6.

Table 6. *Summary of chemical and physical properties of borehole discharge measured during pumping of MG-1425 (MW-1) during aquifer-isolation tests at the North Penn Area 12 Superfund Site, Worcester Township, Montgomery County, Pa.*

[µS/cm, microsiemens per centimeter; mg/L, milligrams per liter; °C, degrees Celsius; ft, feet]

Time	pH	Specific conductance (µS/cm at 25°C)	Turbidity units	Dissolved oxygen (mg/L)	Temperature (°C)
		MG-1425 (MW-1) 92-102 ft below top of casing (started pumping at 12:22 on 3-16-95)			
12:30	7.3	680	7	5.9	16
12:40	7.6	630	2	4.6	17
12:55	7.7	640	2	4.5	17
13:07	7.6	640	2	4.3	17
		MG-1425 (MW-1) above 90 ft below top of casing (started pumping at 15:47 on 3-16-95)			
15:55	7.6	600	2	4.6	14
16:04	7.6	610	3	5.4	14
16:10	7.6	600	3	5.9	14
16:23	7.7	600	2	5.9	14
16:35	7.7	610	1	6.1	14
16:42	7.7	610	1	6.4	14
16:48	7.6	610	1	6.6	14

MG-1426 (MW-2)

The caliper log (fig. 5) shows the total depth of the borehole is 112 ft below top of casing and it is cased with 6-in.-diameter casing to 25 ft below top of casing. The depth to water was 68.33 ft below top of casing at the time of logging. The caliper log shows openings above the water level at 34.5-35.5, 45-47.5, 55 and 64-65 ft below top of casing; at the water level at 68 ft below top of casing; and below the water level at 74-80 and 101-104 ft below top of casing. The borehole television survey shows the orientation of most major fractures is vertical, including fractures at 35, 75, and 76 ft below top of casing. Numerous other minor vertical (at 39 and 53 ft below top of casing, for example) and horizontal fractures (at 55, 77, 79, and 104 ft below top of casing, for example) can be seen in the open borehole interval, as well as calcite veins and alternating gray and red siltstone. The television survey also showed the borehole walls were wet from seepage below casing near 28, 33, 38, and 55 ft below top of casing.

The fluid-resistivity log (fig. 5) shows a gradual decrease with depth (increase in fluid conductivity) with very small inflections in slope at 71, 80, and 106 ft below top of casing. The inflections on the fluid-resistivity log suggest the fractures near those depths may produce fluid. The fluid-temperature log shows a gradual increase in temperature with depth, indicating little or no borehole flow. Under nonpumping conditions, the heat-pulse flowmeter was used to test for vertical borehole-fluid movement at several depths (table 7). No flow was detected at half the depths tested. A small amount (near the method's lower limit of measurement of 0.01 gal/min) of upward flow was measured at 77, 82, 95, and 100 ft below top of casing, which indicates possible inflow at the fracture at 104 ft below top of casing and outflow at fractures near 75-76 ft below top of casing. Under pumping conditions (at a rate of about 0.46 gal/min), the interval between at 75 and 80 ft below top of casing produced most of the fluid; between 80 and 100 ft below top of casing, the production rate was small and nearly constant. At 105 ft below top of casing, flow, if present, was less than 0.01 gal/min, indicating that the fracture at 104 ft below top of casing produced a minor amount of fluid.

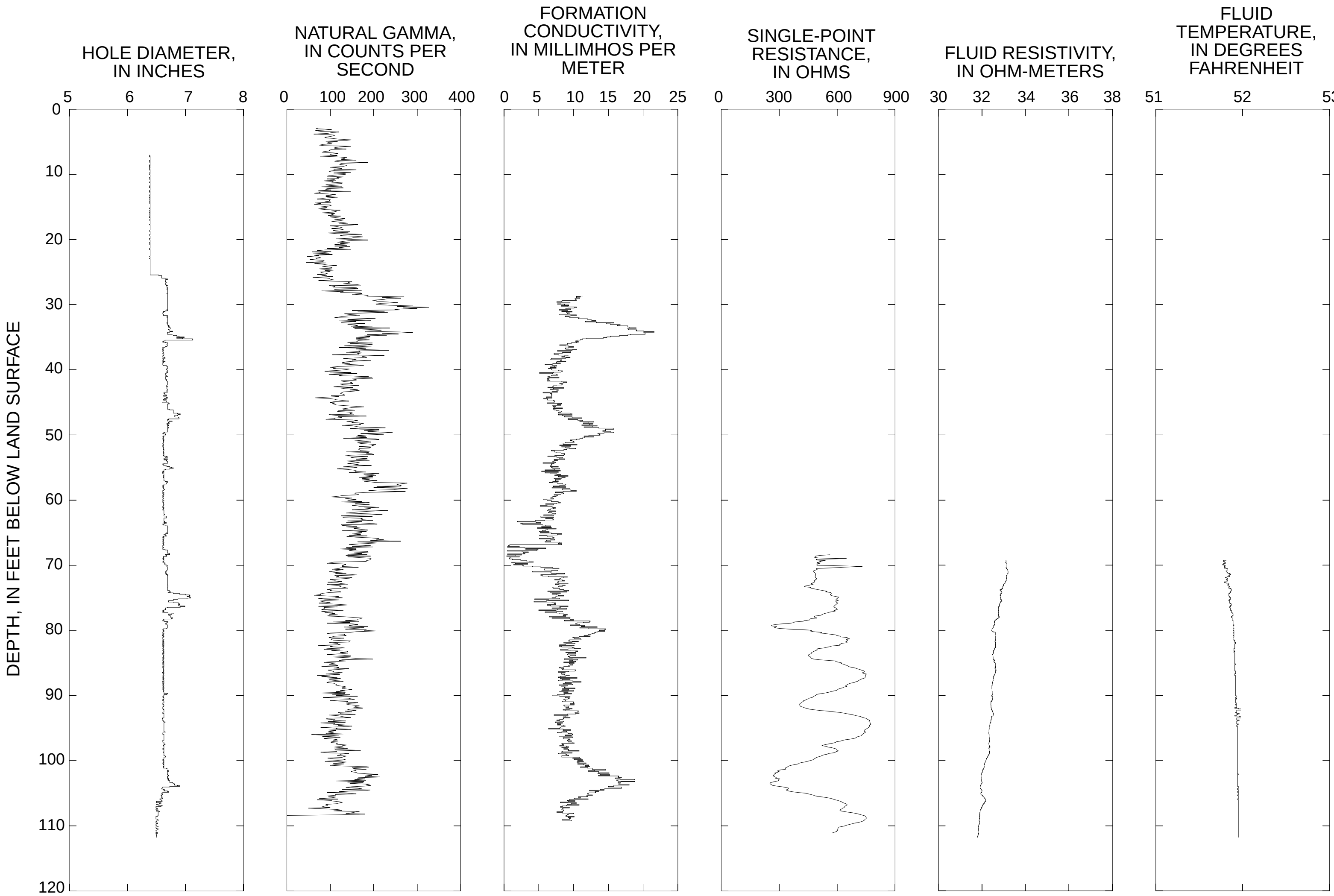

Figure 5. Geophysical logs for borehole MG-1426 (MW-2), North Penn Area 12 Superfund Site, Worcester Township, Montgomery County, Pa.

Table 7. *Summary of heat-pulse-flowmeter measurements under nonpumping and pumping conditions in well MG-1426 (MW-2), North Penn Area 12 Superfund Site, Worcester Township, Montgomery County, Pa.*

[ft, feet; gal/min, gallons per minute; ND, not detected; --, not tested]

Depth of heat-pulse release (ft below top of casing)	Nonpumping conditions[1]		Pumping conditions[2]	
	Flow rate (gal/min)	Flow direction	Flow rate (gal/min)	Flow direction
72.5	ND		[3] 0.205	up
73.6	--		.305	up
75.2	ND		--	
77	0.011	up	.197	up
82	.013	up	.040	up
95	.012	up	.042	up
100	.011	up	.031	up
105.5	ND		ND	
108	ND		--	

[1] February 24, 1995, depth to water was 68.33 ft below top of casing.
[2] February 27, 1995, depth to water was 68.35 ft below top of casing before pumping; pumping rate was about 0.46 gal/min; pump set at about 72 ft below top of casing.
[3] Measured flow rate may be less than actual because heat-pulse flowmeter was in a fractured portion of the well, and some flow may have bypassed the diverter.

On the basis of results of geophysical logging, a single packer was set in the borehole at 85 ft below top of casing to isolate an upper (above 85 ft below top of casing) and lower (below 85 ft below top of casing) interval on March 14, 1995 (fig. 5). Depth to water in the open borehole was 66.47 ft below top of casing. The water level in the lower interval was only 0.04 ft higher than the water level in the upper interval (table 8), which is consistent with a very small potential for upward flow. The lower interval was pumped at a rate of about 1.2 gal / min. When the lower interval was pumped, drawdown was observed in both the upper and lower intervals (table 8). However, the drawdown in the upper interval was less than in the lower interval. If the packers effectively isolated the intervals inside the borehole, the observed drawdowns show that the intervals are connected outside the borehole.

Table 8. *Depths, water levels, and specific capacity of intervals isolated by packers in borehole MG-1426 (MW-2) at the North Penn Area 12 Superfund Site, Worcester Township, Montgomery County, Pa.*

[ft, feet; gal/min, gallons per minute; (gal/min)/ft, gallons per minute per foot; --, not tested]

Depth of isolated interval in borehole (ft below top of casing)	Pre-pumping depth to water in interval[1] (ft below top of casing)	Depth to water in interval at end of test[2] (ft below top of casing)	Drawdown (feet)	Pumping rate (gal/min)	Pumping duration (minutes)	Specific capacity [(gal/min)/ft]
2-27-95 test						
Open hole pumped	68.35	70.04	1.69	0.46	39	0.27
3-14-95 Test						
Open hole	66.47	--	--	--	--	--
Above 84	66.31	69.05	2.74	--	--	--
Below 86 (pumped)	66.27	71.58	5.31	1.2	28	[3].23

[1] Packers inflated. Water levels reported after they stabilized.
[2] Depth to water reported at end of constant pumping rate before pump shut off.
[3] Calculated specific capacity for interval greater than actual specific capacity because of contributions from other intervals.

The packer was raised 4 ft to determine if differences in initial hydraulic heads might result from a different packer seal. As with the first test, little differences in hydraulic heads in the upper and lower intervals were observed, showing that fractures in upper and lower part of the borehole were hydraulically connected outside the borehole. Because the packers did not effectively isolate intervals in this borehole, no further testing was done.

The calculated specific capacity for the lower interval in this borehole (table 8) probably is greater than the actual specific capacity for the interval because of contribution from the upper interval. Heat-pulse-flowmeter measurements on February 27, 1995, show that the upper interval is more permeable than the lower interval. The specific capacity determined for the open borehole in February 1995 is similar to that of the lower interval determined in March 1995 (table 8).

MG-1427 (MW-3)

The caliper log (fig. 6) shows the total depth of the borehole is 161 ft below top of casing and it is cased with 6-in.-diameter casing to 23 ft below top of casing. Apparently, two different diameter drill bits were used, resulting in a 6.6-in.-diameter borehole from 23 to 123 ft below top of casing and a 6.2-in.-diameter borehole from 123 to 161 ft below top of casing. The depth to water was 59.38 ft below top of casing at the time of logging. The caliper log shows openings above the water level at 24-25 and 30-38 ft below top of casing and below the water level at 64, 69-70, 79.5-87, 91-92, and 110 ft below top of casing. The borehole television survey shows the orientation of most major fractures is vertical, including fractures at 31-37, 70, 79.5-85, and 110 ft below top of casing. Numerous other minor vertical and horizontal fractures can be seen along the open borehole interval, as well as both white (calcite) and dark veins.

The fluid-temperature and fluid-resistivity logs (fig. 6) show almost no gradient from water level to the bottom of the borehole, possibly indicating borehole flow. Under nonpumping conditions, the heat-pulse flowmeter was used to test for vertical borehole fluid movement at 62, 74, 89, 105, 130, and 150 ft below top of casing. No flow was measured at the depths tested. If present, borehole flow is less than the method’s lower limit of measurement (0.01 gal / min).

MG-1428 (MW-4)

A borehole television survey done in MG-1428 (MW-4) showed the bottom of casing was about 36 ft below top of casing. Vertical fractures could be seen just below casing at 49.3 ft below top of casing and at 53, 55, 67-68, and 95-97 ft below top of casing. The bottom of the borehole was at 111.3 ft below top of casing.

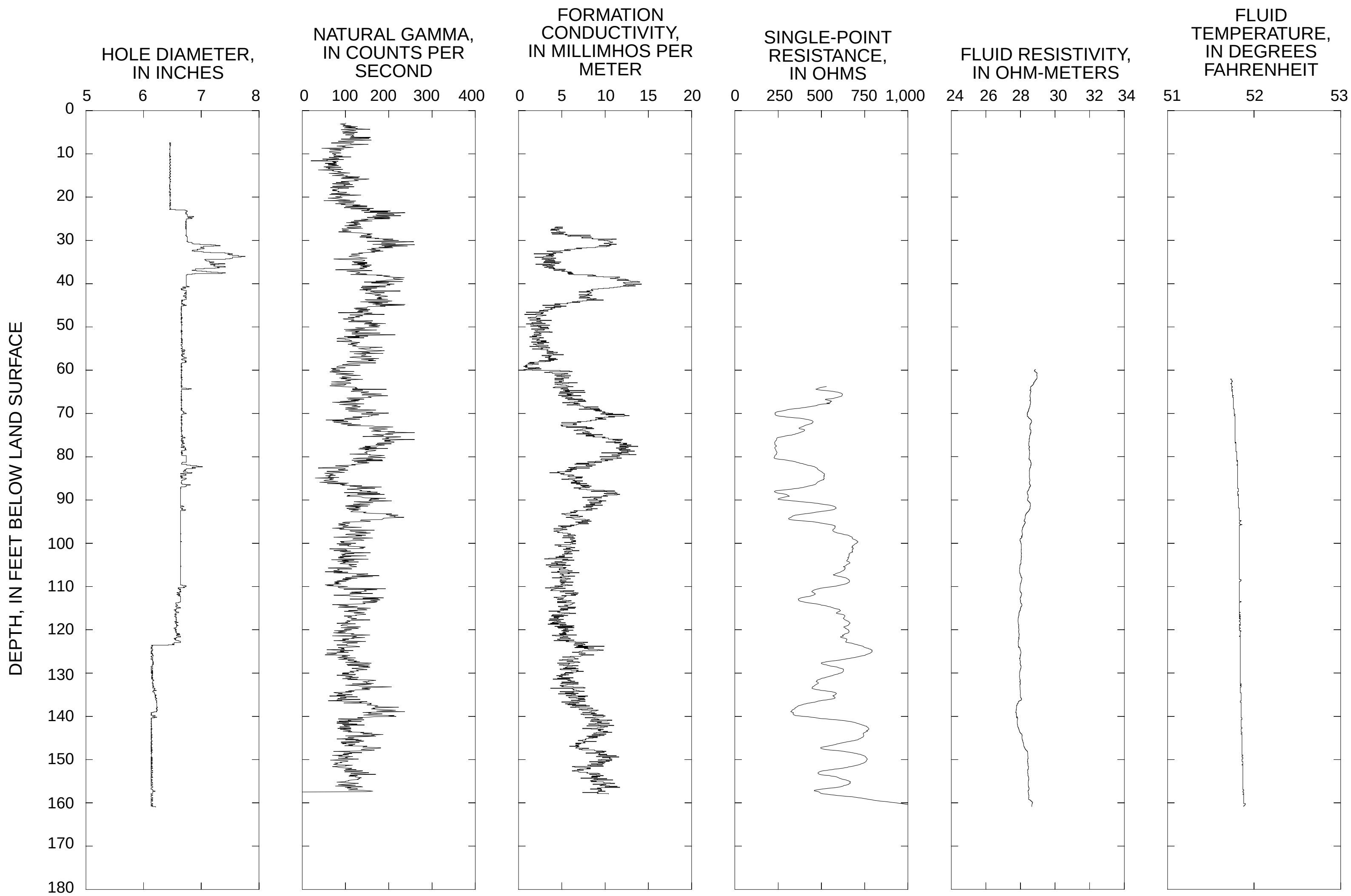

Figure 6. Geophysical logs for borehole MG-1427 (MW-3), North Penn Area 12 Superfund Site, Worcester Township, Montgomery County, Pa.

MG-1430 (T-3)

The caliper log (fig. 7) shows the total depth of the borehole is 305 ft below top of pad and it is cased with 6-in.-diameter casing to 45 ft below top of pad. The depth to water was about 18.46 ft below top of pad at the time of logging. The rough and narrowed borehole shown on the caliper log from 25 to 45 ft below top of pad is caused by encrustations on the steel casing below the water level. Large (iron-oxide?) encrustations can be seen on the inside of casing below the water level in the borehole television survey. The caliper log shows major openings just below casing at 46-49 ft below top of pad and at 57, 59, 77, 99-102, and 104-109 ft below top of pad. At the largest opening, at 106.5 ft below top of pad, the borehole diameter is 13.5 in. The borehole television survey shows the orientation of most fractures is vertical, including fractures at 46-49, 59, 63, and 214 ft below top of casing. Large horizontal fractures are at 56 and 76 ft below top of pad. Numerous other minor vertical and horizontal fractures can be seen along the open borehole interval, as well as white (calcite) veins.

The fluid-resistivity log (fig. 7) shows inflections at 108, 217, and 243 ft below top of pad. From 217 to 245 ft below top of pad, fluid resistivity gradually decreases (dissolved-solids concentration increases) with depth. Almost no gradient is present in the intervals from 52 to 217 ft below top of pad and 245 to 305 ft below top of pad, indicating possible borehole flow. The fluid-temperature log shows no gradient from 45 to 110 ft below top of pad, a gradual decrease from 110 to 170 ft below top of pad, and a gradual increase from 170 ft below top of pad to the bottom of the hole. The heat-pulse flowmeter was used to test for vertical borehole-fluid movement at several depths under nonpumping conditions (table 9). Downward flow at an average rate of 0.9 gal/min was detected in the interval from 50 to 99 ft below top of pad. In the highly fractured interval between 45 and 110 ft below top of pad, some reported flow rates (table 9) probably are less than actual rates because some flow may bypass the flowmeter in intervals where the borehole is enlarged. For example, flow rates in the fracture interval between 100 and 110 ft below top of pad probably were greater than 0.01 gal/min but were not measurable with the heat-pulse flowmeter because of fluid bypassing the flowmeter in fracture openings. Below 110 ft below top of pad, flow rates were very small to negligible. No flow was measured at depths tested below 232 ft below top of pad. The heat-pulse flowmeter data and the geophysical logs indicate water is moving into the borehole through openings between 45 and 90 ft below top of pad and moving down and out of the borehole through openings between 95 and 110 ft below top of pad. Other minor flow patterns may be active at very low flow rates in the interval from 107 to 232 ft below top of pad.

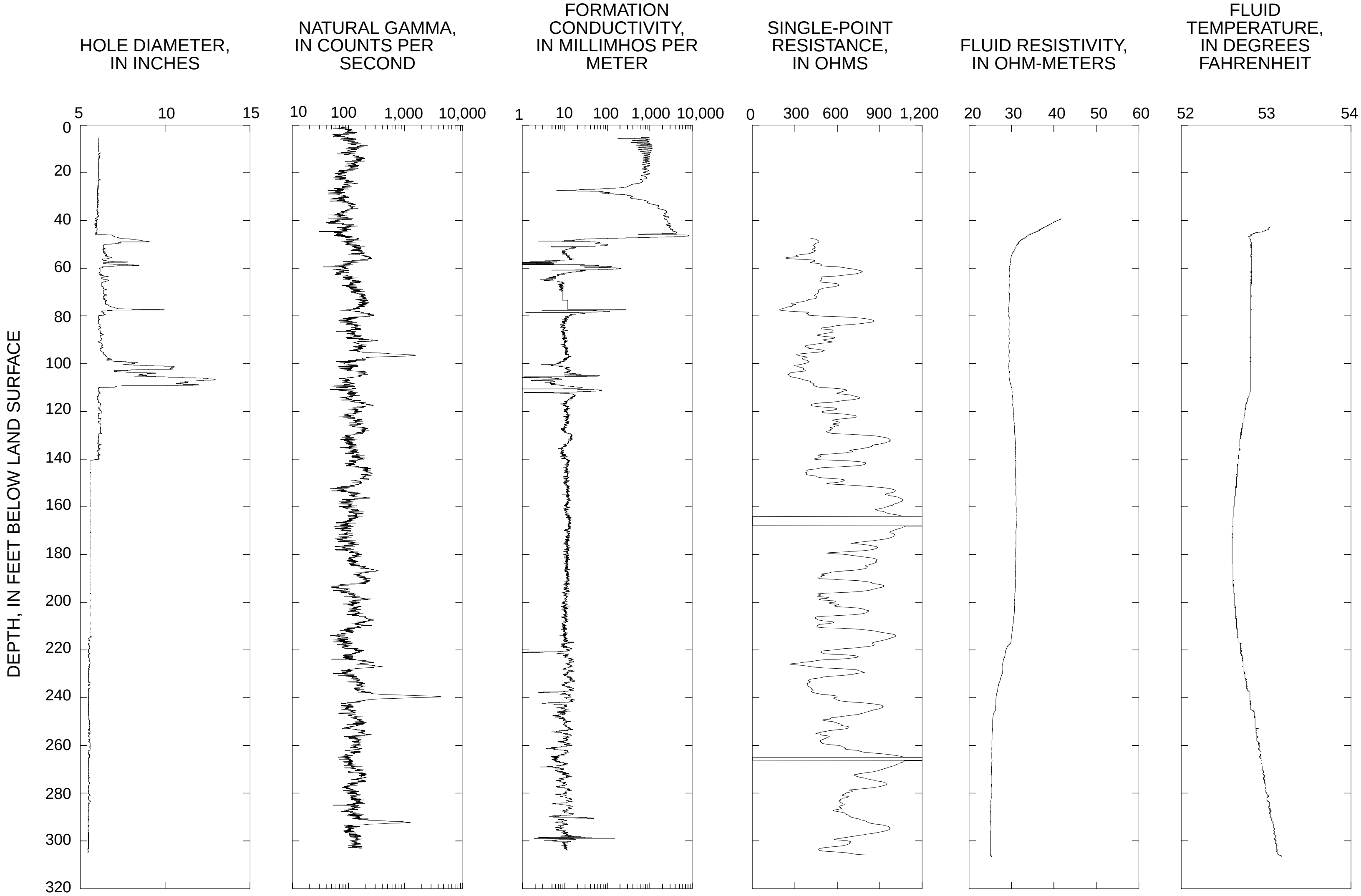

Figure 7. Geophysical logs for borehole MG-1430 (T-3), North Penn Area 12 Superfund Site, Worcester Township, Montgomery County, Pa.

Table 9. *Summary of heat-pulse-flowmeter measurements under nonpumping conditions in well MG-1430 (T-3), North Penn Area 12 Superfund Site, Worcester Township, Montgomery County, Pa., February 26, 1995*

[ft, feet; gal/min, gallons per minute; ND, not detected]

Depth of heat-pulse release (ft below top of concrete pad)	Flow rate (gal/min)	Flow direction
30	ND	
35	ND	
40	ND	
50	[1] 0.028	Down
51	[1].059	Down
62	[1].058	Down
71	[1].10	Down
83	[1].161	Down
86	[1].133	Down
98	[1].112	Down
99	[1].050	Down
101	ND	
107	ND	
144	.01	Down
177	[2].011	Up
212	.01	Down
232	ND	
257	ND	

[1] In fracture, flow probably greater than reported here.
[2] Measurement repeated but may be in error.

MG-1431 (T-5)

The caliper log (fig. 8) shows the total depth of the borehole is 133 ft below top of pad and it is cased with 6-in.-diameter casing to 24 ft below top of pad. The depth to water was 24.49 ft below top of pad at the time of logging. The caliper log shows major fractures just below casing at 24-36 ft below top of pad and at 41-46, 53-57, 60-61, 62-64, 71, 80-84, 85-88, 91-92, 94-95, and 120-122 ft below top of pad; and numerous minor fractures along the open interval of the borehole, including a small fracture at 130 ft below top of pad. The largest fracture in the borehole enlarges the borehole diameter to more than 20 in. at 29 ft below top of pad. The borehole television survey shows the orientation of most major fractures is vertical, although a few large, horizontal fractures are present at 53, 58, 73, and 111 ft below top of pad. Large openings or fractures were noted at 27-36, 53, 62, 81, and 120-121 ft below top of pad. Numerous vertical and horizontal fractures can be seen in the open borehole interval. White (calcite) veins are present near the bottom of the hole.

The fluid-resistivity log (fig. 8) shows inflections at 30, 37, 73, 88, and 95 ft below top of pad. Almost no gradient is present in the intervals between the inflections, indicating possible borehole flow in these intervals. The fluid-temperature log shows a slight increase in temperature from 26 to about 35 ft below top of pad and little to no gradient from about 35 to 124 ft below top of pad. At the bottom of the hole, there is a gradual decrease in fluid temperature from 127 to 132 ft below top of pad. The heat-pulse flowmeter was used to test for vertical borehole-fluid movement at several depths under nonpumping conditions (table 10). Because flow rates in most intervals exceeded the flowmeter’s upper limit of measurement (1 gal / min), an alternative technique to estimate flow was adopted. By using a 5-in.-diameter diverter that is smaller than the diameter of the borehole, flow through the meter was reduced,

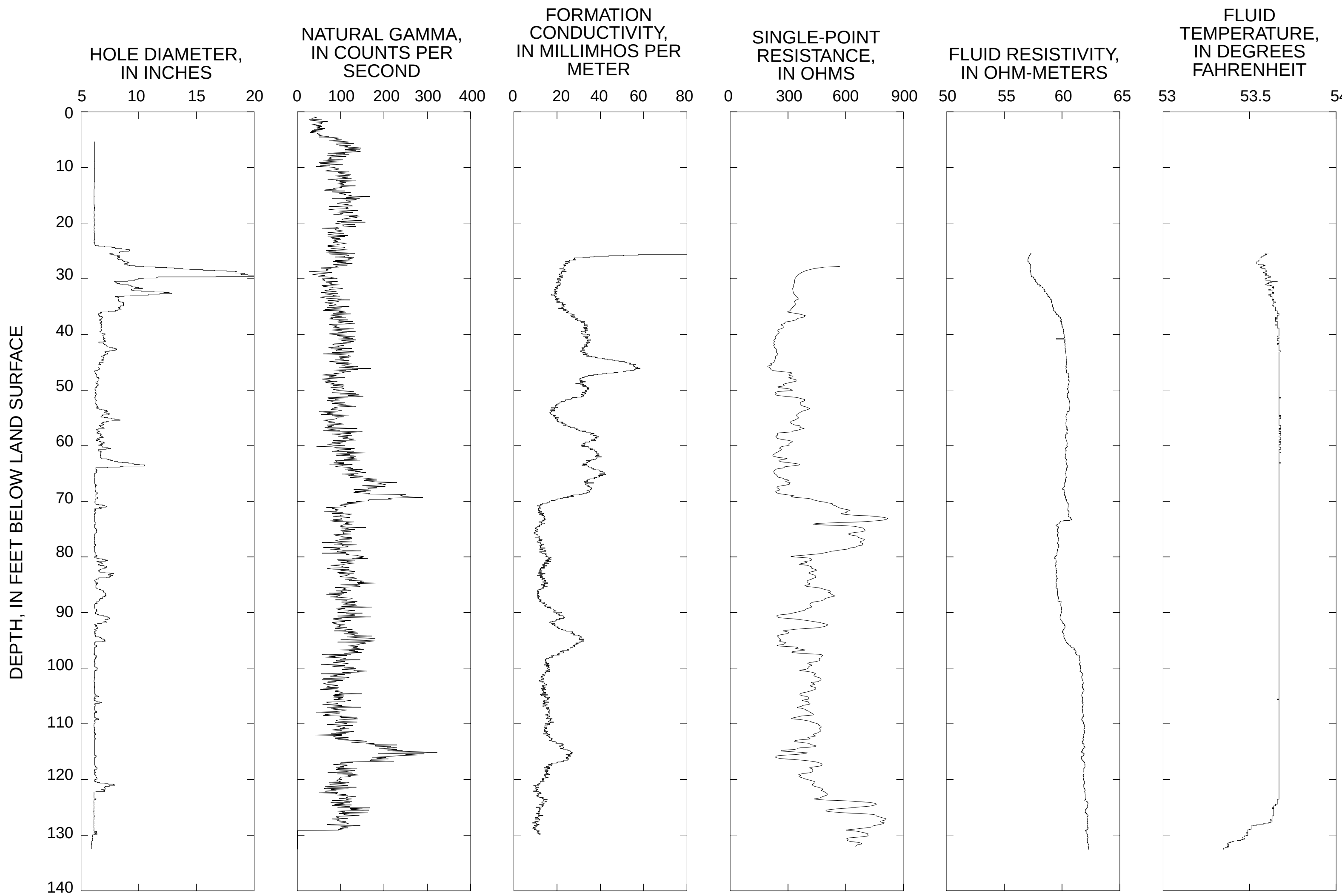

Figure 8. Geophysical logs for borehole MG-1431 (T-5), North Penn Area 12 Superfund Site, Worcester Township, Montgomery County, Pa.

***Table 10.** Summary of heat-pulse-flowmeter measurements under nonpumping conditions in well MG-1431 (T-5), North Penn Area 12 Superfund Site, Worcester Township, Montgomery County, Pa., February 25, 1995*

[ft, feet; gal/min, gallons per minute]

Depth of heat-pulse release (ft below top of pad)	Nonpumping uncorrected[1] flow rate (gal/min)	Hole diameter (inches)	Correction factor[2]	Corrected flow rate[3] (gal/min)	Flow direction
39	0.226	6.75	7.74	1.75	Down
51.5	.508	6.25	5.29	2.69	Down
66	.472	6.20	5.06	2.39	Down
73.3	.508	6.20	5.06	2.57	Down
76.5	.440	6.20	5.06	2.23	Down
88.6	.171	6.20	5.06	.86	Down
93.5	.144	6.40	6.01	.73	Down
103	.118	6.20	5.06	.60	Down
114	.093	6.20	5.06	.47	Down
126	.010	6.10	4.60	.05	Down
131	.011	5.90	3.69	.04	Up

[1] Raw data from flowmeter with 5-in. diverter, uncorrected for loss around outside edges of diverter.
[2] Correction factor = $(r_w^2 - r_d^2)/r_h^2$, where r_w is radius of well, r_d is radius of diverter (2.5 in.), and r_h is radius of flowmeter (0.815 in.).
[3] Flow rate corrected for estimated losses around outside of diverter.

allowing determination of flow direction and estimation of flow rate. Therefore, reported flow rates (table 10) are less than actual rates because some flow bypasses the flowmeter. The static water level was 24.26 ft below top of pad when the well was tested on February 27, 1995. Generally, downward flow was measured at increasing rates in the interval from 39 to 73 ft below top of pad; the downward flow rate decreases from 76 to 126 ft below top of pad. Corrected flow rates were estimated to be 2.6 gal / min or greater near 73 ft below top of pad. Below 120 ft below top of pad, flow rates were very small to negligible.

The heat-pulse flowmeter measurements and geophysical logs indicate water is flowing into the borehole through fractures between 25 and 73 ft below top of pad, moving downward, and exiting the borehole through fractures between 75 and 120 ft below top of pad.

On the basis of results of geophysical logging and the borehole television survey, a single packer was set in the borehole at 73 ft below top of pad to isolate an upper (above 72 ft below top of pad) and lower (below 74 ft below top of pad) interval on March 17, 1995. Depth to water in the open borehole was 18.18 ft below top of pad. After the packer was inflated and water levels stabilized, the measured water level in the upper interval was 2.81 ft higher than the water level in the lower interval, showing a potential for downward flow in the borehole. The lower interval was pumped at a rate of about 3 gal / min. When the lower interval was pumped, very little drawdown was observed in the upper interval (fig. 9, table 11). The observed drawdowns show the intervals are not well connected outside the borehole. Although the television survey of the borehole showed that the orientation of most fractures was vertical or sub-vertical, the short section between 72 and 74 ft below top of pad was not penetrated by vertical fractures, and the layer may act as a confining bed.

The packer was reinflated on March 20, 1995, at the same depth as on March 17. After the packer was inflated and water levels stabilized, the measured water level in the upper interval was 2.46 ft higher than the water level in the lower interval. The upper interval was pumped at a rate of about 6 gal / min. When the upper interval was pumped, very little drawdown was observed in the lower interval (fig. 9, table 11). The observed drawdowns show that the intervals are not well connected outside the borehole. Pumping of the upper interval was stopped prematurely because of limited volume in the purge-water storage tank; however, the rate of drawdown had begun to decrease (fig. 9) such that the projected drawdown after 60 minutes would be about 1.2 ft.

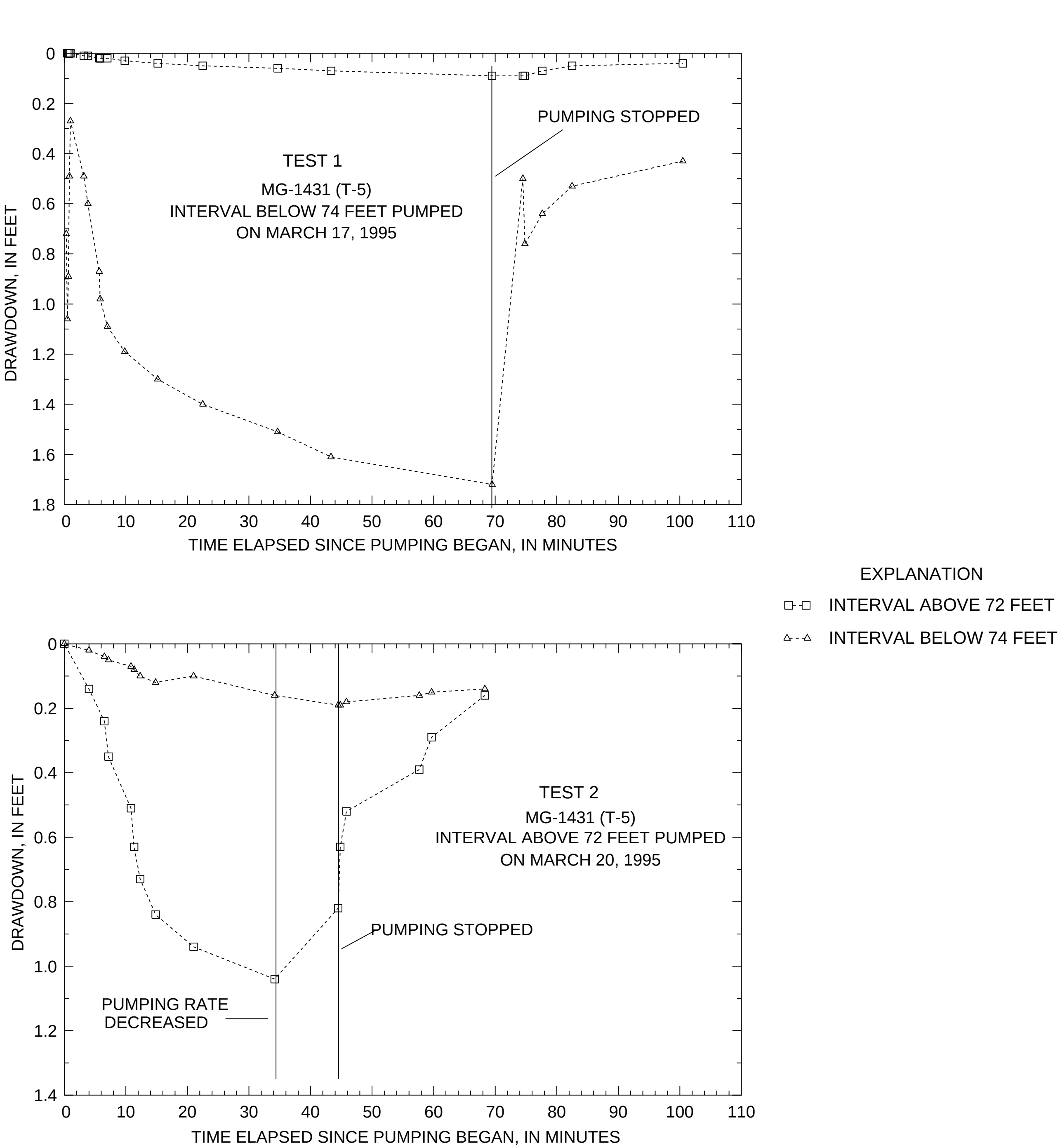

Figure 9. Drawdown as a function of time in two intervals of borehole MG-1431 (T-5) pumped with packer in place at the North Penn Area 12 Superfund Site, Worcester Township, Montgomery County, Pa. [See table 11 for packer location and pumping rates.]

The specific capacity determined from the aquifer-isolation tests was 5.8 (gal / min) / ft (table 12) [or about 5 (gal / min) / ft if projected drawdown of 1.2 ft is used] for the upper interval and 1.7 (gal / min) / ft for the lower interval.

The chemical and physical properties of the borehole discharge measured during the aquifer-isolation tests are given in table 12.

Table 11. *Depths, water levels, and specific capacity of intervals isolated by packers in borehole MG-1431 (T-5) at the North Penn Area 12 Superfund Site, Worcester Township, Montgomery County, Pa.*

[ft, feet; gal/min, gallons per minute; (gal/min)/ft, gallons per minute per foot; --, not tested]

Depth of isolated interval in borehole (ft below top of pad)	Pre-pumping depth to water in interval[1] (ft below top of pad)	Depth to water in interval at end of test[2] (ft below top of pad)	Drawdown (ft)	Pumping rate (gal/min)	Pumping duration (minutes)	Specific capacity [(gal/min)/ft]
3-17-95 test						
Open hole	18.18	--	--	--	--	--
Above 72	17.90	17.99	0.09	--	--	--
Below 74 (pumped)	20.71	22.73	1.72	3	60	1.7
3-20-95 test						
Open hole	19.39	--	--	--	--	--
Above 72 (pumped)	18.73	19.77	1.04	6	30	5.8
Below 74	21.19	21.35	.16	--	--	--

[1] Packers inflated. Water levels reported after they stabilized.
[2] Depth to water reported at end of constant pumping rate before pump shut off.

Table 12. *Summary of chemical and physical properties of borehole discharge measured during pumping of MG-1431 (T-5) during aquifer-isolation tests at the North Penn Area 12 Superfund Site, Worcester Township, Montgomery County, Pa.*

[µS/cm, microsiemens per centimeter; mg/L, milligrams per liter; °C, degrees Celsius]

Time	pH	Specific conductance (µS/cm at 25°C)	Turbidity units	Dissolved oxygen (mg/L)	Temperature (°C)
MG-1431 (T-5) below 74 ft below top of pad (started pumping at 14:48 on 3-17-95)					
14:57	5.4	190	0	7.7	15
15:02	5.6	190	0	7.7	14
15:14	5.7	190	0	8.1	14
15:28	5.7	190	0	8.7	14
15:45	5.7	190	0	7.7	14
MG-1431 (T-5) above 72 ft below top of pad (started pumping at 13:15 on 3-20-95)					
13:25	5.6	200	1	8.2	13
13:36	5.6	200	1	8.6	13
13:43	5.6	200	1	8.5	13
13:49	5.6	200	1	8.6	13

MG-1432 (T-6)

The caliper log (fig. 10) shows the total depth of the borehole is about 904 ft below top of casing and it is cased with 6-in.-diameter casing to 21 ft below top of casing. The depth to water was 64.35 ft below top of casing at the time of logging (table 3). The caliper log shows openings above the water level at 23-25, 38-43, 45-46, 49-50, and 54-55 ft below top of casing and below the water level at 66-68, 74-75, 78-82, 85-89, 92-96, 171-173, 692-693, and 859-860 ft below top of casing. A few very small openings are at 240, 452, 469, 486, 523, 526, 638, 736, and 749 ft below top of casing. Most fractures are at depths less than 100 ft below top of casing. At the largest opening at 88 ft below top of casing, the borehole diameter is 8.5 in. The borehole television survey shows the orientation of most major fractures is vertical, although at least one large, horizontal fracture is present at 172 ft below top of pad. Fractures for which there is no corresponding opening on the caliper log include vertical fractures at 251, 287, and 445 ft below top of casing and a horizontal fracture at 320 ft below top of casing. Numerous vertical and horizontal fractures filled with calcite are present throughout the open interval of the borehole. Cascading water can be seen in the television survey along the borehole walls above the water level; this water appears to enter the borehole at 53.6 ft below top of casing.

The fluid-resistivity log (fig. 10) shows inflections at 67, 88, and 457 ft below top of casing. Almost no gradient is present in the intervals between the inflections. The fluid-temperature log shows a very gradual decrease from 90 to 170 ft below top of casing, little to no gradient from 170 to 212 ft below top of casing, and a gradual increase from 212 to the bottom of the hole. The fluid-resistivity, fluid-temperature, and caliper logs suggest that openings near 67, 88, 172, 240, and 452 ft below top of casing may be water bearing. The heat-pulse flowmeter was used to test for vertical borehole-fluid movement at several depths under nonpumping conditions (table 13). No flow was detected. Under pumping conditions (at a rate of about 0.97 gal / min), the openings at 85-89 ft below top of casing produced most of the fluid, followed by openings at 78-82 and 74-75 ft below top of casing. The measured flow rate of 0.43 gal / min at 66 ft below top of pad at the topmost opening was 0.54 gal / min less than the overall pumping rate of about 0.97 gal / min, suggesting that the openings at 66-68 ft below top of casing probably produced fluid not accurately measured by the flowmeter. At depths greater than 91 ft below top of casing, no flow was detected. The openings at depths less than 90 ft below top of casing are the most productive in the borehole.

Well MG-1432 (T-6) was pumped on February 23, 1995. The static-water level was 64.67 ft below top of casing, and the water level declined 0.40 ft after pumping for 45 min at 1 gal / min. The specific capacity of 2.5 (gal / min) / ft calculated from these data is about one order of magnitude greater than that of MG-1425 (MW-1) and MG-1426 (MW-2) and similar in magnitude to that of MG-1421 (T-5) (tables 5, 8, 11).

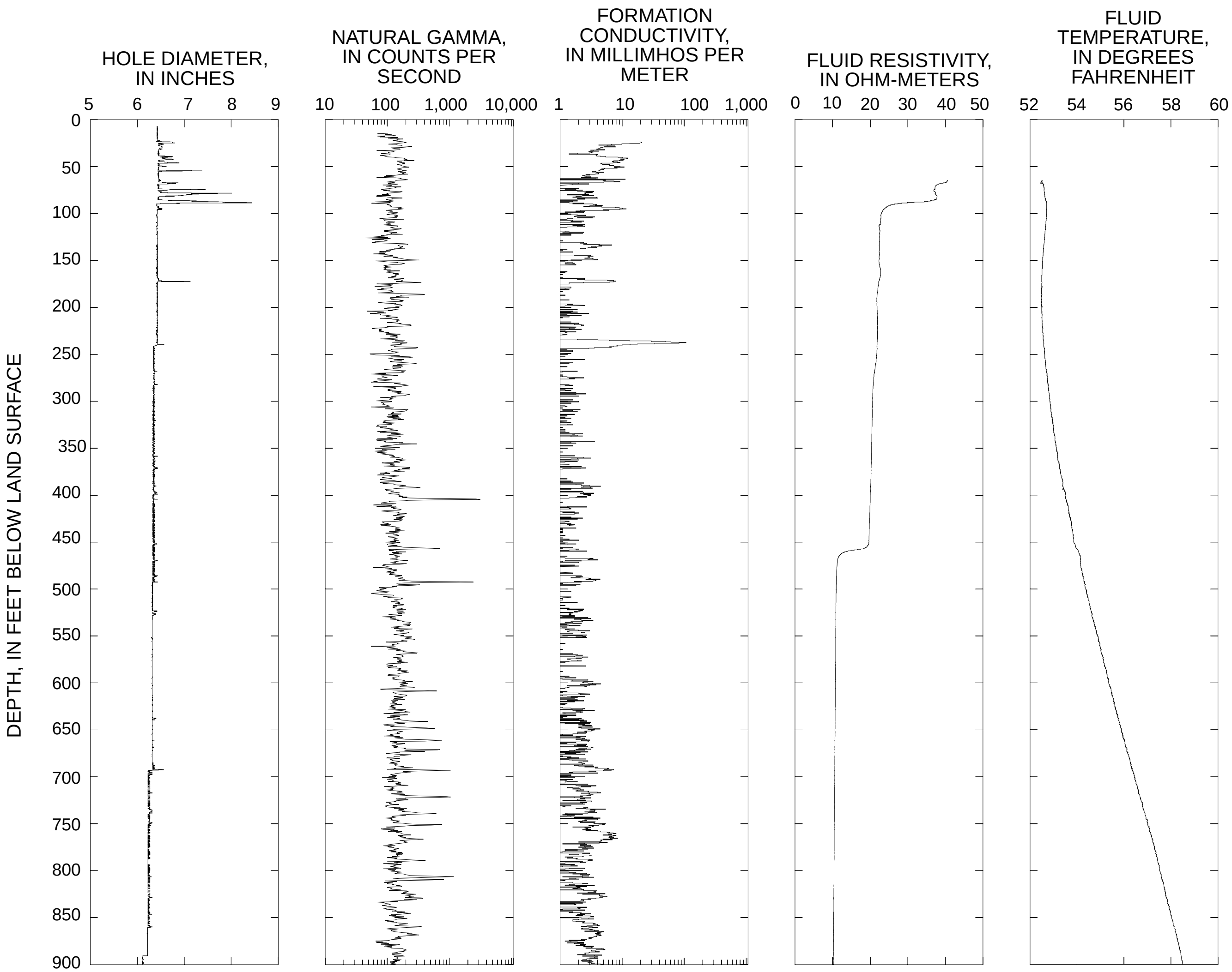

Figure 10. Geophysical logs for borehole MG-1432 (T-6), North Penn Area 12 Superfund Site, Worcester Township, Montgomery County, Pa.

Table 13. *Summary of heat-pulse-flowmeter measurements under nonpumping and pumping conditions in well MG-1432 (T-6), North Penn Area 12 Superfund Site, Worcester Township, Montgomery County, Pa.*

[ft, feet; gal/min, gallons per minute; ND, not detected]

Depth of heat-pulse release (ft below top of casing)	Nonpumping conditions[1]	Pumping conditions[2]	
	Flow rate (gal/min)	Flow rate (gal/min)	Flow direction
66	ND	[3] 0.43	up
71	ND	.573	up
76	ND	.493	up
83	ND	.305	up
91	ND	.027	up
115	ND	ND	
165	ND	ND	
180.5	ND	ND	
230	ND	ND	
250	ND	ND	
450	ND	ND	
470	ND	ND	

[1] February 23, 1995, depth to water was 64.67 ft below top of casing.

[2] February 23, 1995, pumping rate was about 0.97 gal/min; pump set at 67 ft below top of casing.

[3] Depth of flowmeter was 66.5 ft below top of casing, and flow rate measured was probably less than actual because some flow was lost around outside of diverter through fractures that enlarge the borehole.

MG-1438 (MW-12)

The caliper log (fig. 11) shows the total depth of the borehole is 214 ft below top of casing and it is cased with 8-in.-diameter casing to 120 ft below top of casing. The depth to water was 62.75 ft below top of casing at the time of logging. The caliper log shows small openings along the whole length of the open interval below casing (121-125, 136, 139-151, 163-165, 170-189, and 194-198 ft below top of casing). No single opening appears much larger than the others, although the largest borehole diameter (8.45 in.) was recorded at 197 ft below top of casing. A minor constriction is located at 206 ft below top of casing. The borehole television survey shows the orientation of most fractures is vertical, including fractures at 135, 164, 169, 173, and 197 ft below top of casing. Numerous other minor vertical and horizontal fractures can be seen along the open borehole interval, as well as white (calcite) veins. For a few feet at the bottom of the hole, the walls are covered with grout.

In 1990, the borehole was drilled to a depth of 300 ft and then backfilled with bentonite cement (grout) to about 211 ft. On February 21, 1995, the borehole was deepened to 214 ft below top of casing. Fluid-resistivity and fluid-temperature logs (fig. 11) were run soon after redrilling the well, and sufficient time may not have elapsed to allow fluid-resistivity and fluid-temperature gradients to completely stabilize. The fluid-resistivity log shows a gradual decrease (increase in dissolved-solids concentration) with depth from the water level at 63 to 142 ft below top of casing and changes in slope at 142 and 206 ft below top of casing with almost no gradient in between. Because the hole had recently been redrilled (24 hours earlier) through grout, fluid at the bottom of the hole may have contained high dissolved solids. The fluid-temperature log shows a gradual increase from below the bottom of casing to

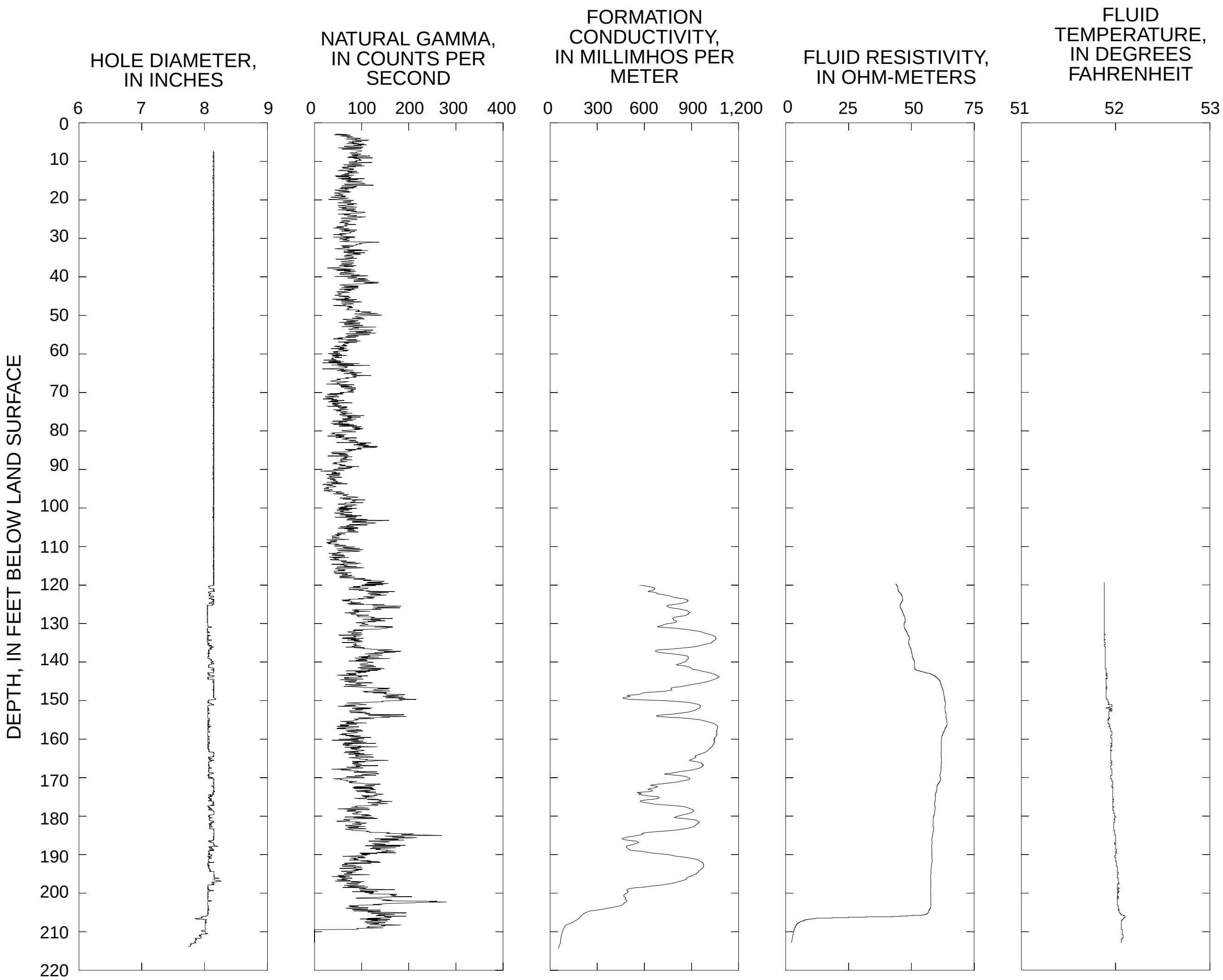

Figure 11. Geophysical logs for borehole MG-1438 (MW-12), North Penn Area 12 Superfund Site, Worcester Township, Montgomery County, Pa.

the bottom of the hole, with a minor perturbation (increase) at 206 ft below top of casing. These fluid logs suggest that openings near 142 and 206 ft below top of casing produce or receive fluid. The heat-pulse flowmeter was used to test for vertical borehole-fluid movement under nonpumping conditions at 90, 135, 147, 160, 202, and 208 ft below top of casing. No flow was detected. If present, borehole flow is less than the method's lower limit of measurement (0.01 gal / min).

MG-1439 (Rehab Center Well)

The caliper log (fig. 12) shows the total depth of the borehole is 498 ft below top of casing and it is cased with 8-in.-diameter casing to 29 ft below top of casing. The depth to water was 50.21 ft below top of casing at the time of logging. The caliper log shows openings above the water level at 40-45 ft below top of casing and below the water level at 56-58, 62-64, 66-70, 71-72, 76-77, 78, 108-109, 147-149, 217-220, 239-240, and 484 ft below top of casing. Most openings are at depths less than 80 ft below top of casing. At the largest opening in the borehole, at 63 ft below top of casing, the borehole diameter is more than 10 in. The borehole television survey shows the orientation of most major fractures is vertical, although horizontal fractures are present at 68 to 71 and 320 ft below top of casing. The water in the borehole was murky from 50 to 59 ft below top of casing and then cleared, indicating possible inflow (or lateral flow) through fractures at 56-58 ft below top of casing. Borehole water became increasingly clearer at 68 and 99 ft below top of casing.

The fluid-resistivity log (fig. 12) shows inflections at 54, 304, and 485 ft below top of casing. Almost no gradient is present in the intervals between the inflections. The fluid-resistivity and caliper logs suggest that openings near 56-58 ft below top of casing may be water bearing. The inflection near 304 ft below top of casing in the fluid-resistivity log may be related to borehole circulation affected by long-term pumping in the well; the pump was set near 300 ft below top of casing and was removed only about 14 hours before logging. The single-point resistance log indicates a change in lithology below 300 ft. The very high conductance of the fluid in the intervals from 305 to 485 ft and from 485 to 498 ft below top of casing suggests that ground water in these deeper intervals is not well connected to that in shallower intervals and may be relatively stagnant in the borehole. The fluid-temperature log shows a slight decrease from 60 to 175 ft, a slight increase from 175 to about 300 ft, and then a gradual increase from 300 ft below top of casing to the bottom of the hole. The heat-pulse flowmeter was used to test for vertical borehole-fluid movement at several depths under nonpumping conditions (table 14). Generally, upward flow at a rate up to 0.04 gal / min was measured in the interval from 110 to 65 ft below top of pad. No flow was measured at depths greater than 155 ft below top of casing or less than 60 ft below top of casing, probably because the rate of flow, if present, is less than the method's lower limit of measurement (0.01 gal / min). The heat-pulse-flowmeter data and the geophysical logs indicate that water may enter the borehole through openings near 109 and 149 ft below top of casing, flow upward, and exit the borehole through the large opening near 63 ft below top of casing.

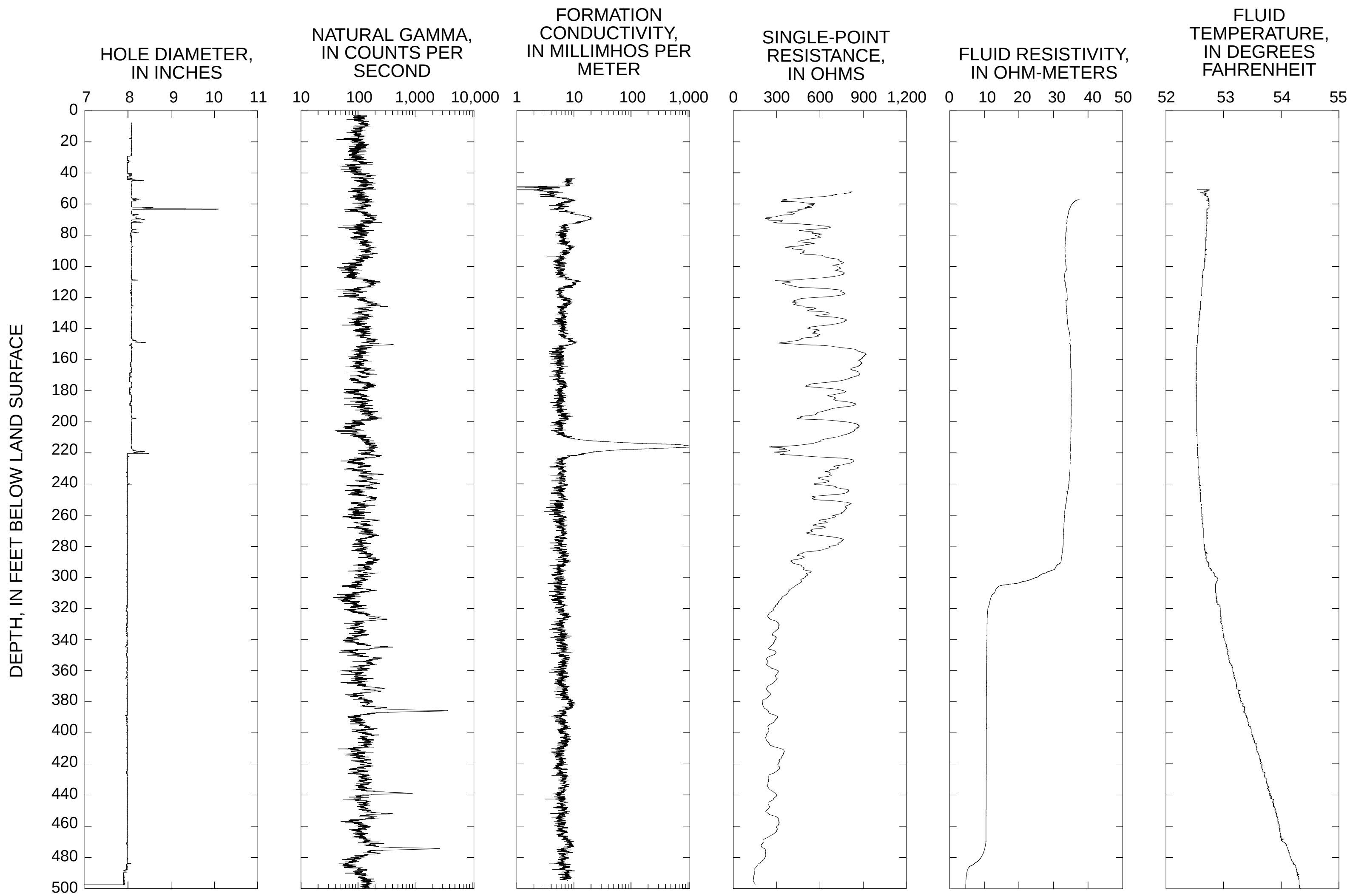

Figure 12. Geophysical logs for borehole MG-1439 (Rehab Center), North Penn Area 12 Superfund Site, Worcester Township, Montgomery County, Pa.

Table 14. *Summary of heat-pulse-flowmeter measurements under nonpumping conditions in well MG-1439 (Rehab Center), North Penn Area 12 Superfund Site, Worcester Township, Montgomery County, Pa.*

[ft, feet; gal/min, gallons per minute; ND, not detected]

Depth of heat-pulse release (ft below top of concrete pad)	Nonpumping conditions[1]	
	Flow rate (gal/min)	Flow direction
52.5	ND	
55	ND	
60	ND	
65	0.026	Up
80	.033	Up
100	.037	Up
110	.027	Up
155	ND	
212	ND	
230	ND	
290	ND	
310	ND	
400	ND	

[1] February 25, 1995, depth to water was 50.21 ft below top of casing.

COMPARISON OF GEOPHYSICAL LOGS AND RESULTS OF AQUIFER-ISOLATION TESTS

Lithologic correlations using gamma and EM logs can be made in three of the deepest wells: MG-1430 (T-3), MG-1432 (T-6), and MG-1439 (Rehab Center). Thin, distinct intervals of elevated gamma activities could be correlated between MG-1430 (T-3) at depths near 250-300 ft below top of pad and MG-1432 (T-6) and MG-1439 (Rehab Center) at depths near 400-500 ft. For example, the gamma peak at 404 ft below top of casing in well MG-1432 (T-6) correlated with a gamma peak at 386 ft below top of casing in well MG-1439 (Rehab Center) and at 240 ft below top of pad in well MG-1430 (T-3) (fig. 13). The zones match with an offset of about 22 ft for wells MG-1432 (T-6) and MG-1439 (Rehab Center) and by an

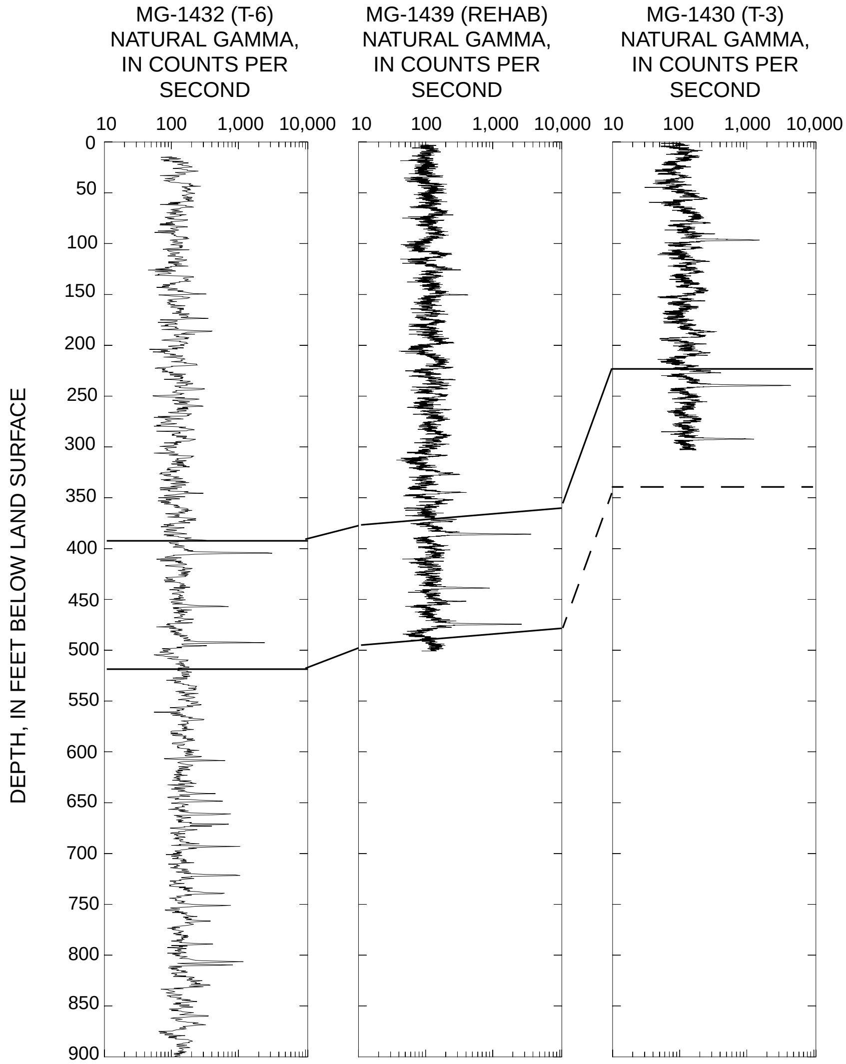

Figure 13. Natural-gamma logs for boreholes MG-1432 (T-6), MG-1439 (Rehab Center), and MG-1430 (T-3), North Penn Area 12 Superfund Site, Worcester Township, Montgomery County, Pa. [Logs plotted at same scale for comparison.]

offset of about 146 ft between wells MG-1430 (T-3) and MG-1439 (Rehab Center). In addition, a narrow interval of elevated formation conductivity shown on the EM log at 238 ft below top of casing in well MG-1432 (T-6) correlates with a similar feature at 216 ft below top of casing in well MG-1439 (Rehab Center) (fig. 14). These intervals of elevated formation conductivity appear to be associated with a narrow band of mineralization that can be seen on the borehole television survey of MG-1432 (T-6). Correcting for an estimated difference in elevation, the intervals in MG-1432 (T-6) and MG-1439 (Rehab Center) are nearly horizontal. Thus, assuming that these two deep boreholes lie along strike because of the lithologic correlation, the strike of the beds is estimated to be about N64°E. The dip of the beds is estimated to be 15°NW from the offset in well MG-1430 (T-3). Several fractures at depth also appear to correlate between the two boreholes along strike.

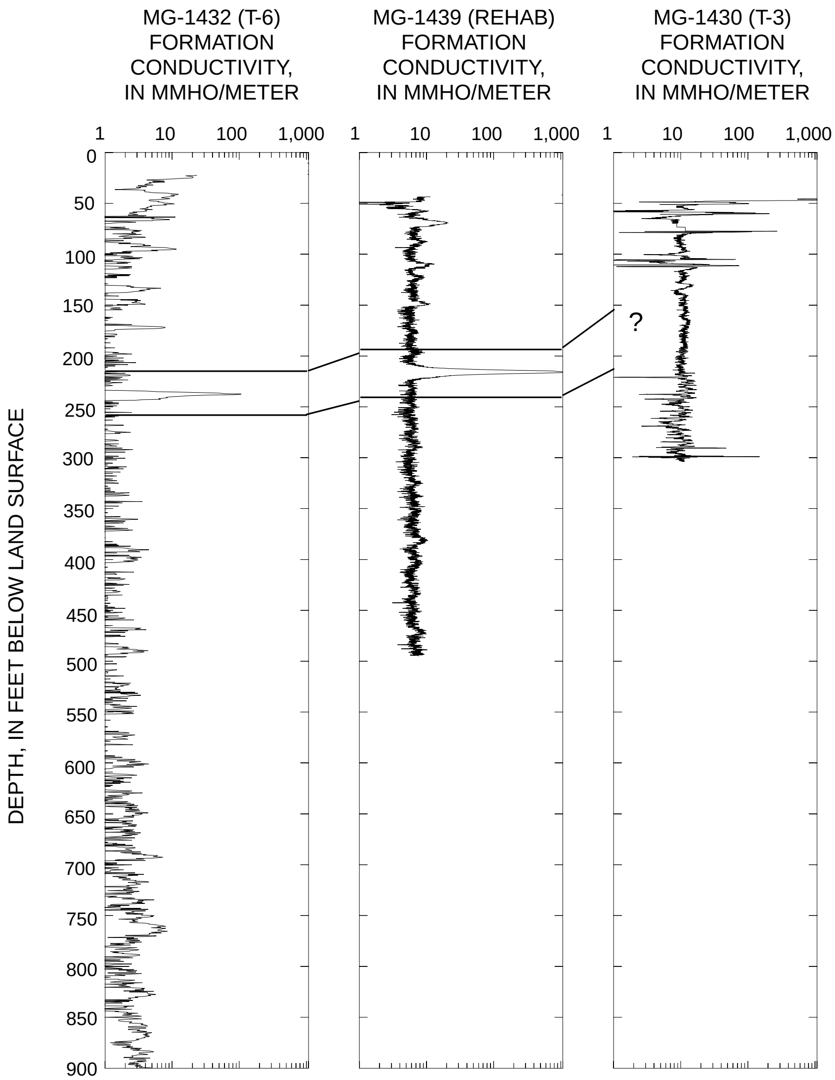

Figure 14. Electromagnetic logs for boreholes MG-1432 (T-6), MG-1439 (Rehab Center), and MG-1430 (T-3), North Penn Area 12 Superfund Site, Worcester Township, Montgomery County, Pa. [Logs plotted at same scale for comparison.]

Fractures at depths less than 100 ft occur more frequently and generally appear to be more productive than fractures at depths greater than 100 ft for all wells logged. Results of the aquifer-isolation tests also indicate that shallow water-bearing zones were more productive than deep zones. Fluid resistivity is a measure of the dissolved-solids concentrations from natural mineral sources or contaminants introduced into ground water. The fluid resistivity of water in shallow zones usually was greater (indicating more dilute water) than that in deeper zones of the boreholes, suggesting that the residence time for water in the shallow part of the ground-water system is shorter, assuming that ground water acquires solutes in proportion to the amount of time that it is in contact with aquifer materials. Of the shallow boreholes logged, MG-1425 (MW-1) had the lowest fluid resistivity (highest fluid conductivity) (figs. 5, 6, 7, 8, 10, 11, 12).

Temperatures of shallow water ranged from about 52° to 54°F. Increases in borehole-fluid temperature with depth caused by the geothermal gradient appear to begin at about 180-200 ft below land surface.

The rate and direction of fluid movement under nonpumping conditions differs in the boreholes logged. If no flow was detected, a lack of differences in hydraulic head for each fracture in the boreholes is indicated. If flow was detected, a difference in hydraulic head between fractures is indicated. Differences in hydraulic head could be related to nearby pumping, different flow systems and discharge zones, or different positions within the flow system. On the northwest part of the site, no flow was detected in MG-1427 (MW-3), MG-1429 (MW-12), and MG-1432 (T-6), and very small amounts of flow were measured in MG-1425 (MW-1) (downward) and MG-1426 (MW-2) (upward). On the southwest part of the site, downward flow was measured in MG-1430 (T-3) and MG-1431 (T-5), and flow rate in MG-1431 (T-5) probably was greater than 2 gal / min downward. Upward flow was measured in MG-1439 (Rehab Center). Ground-water seepage or cascading water was noted above the water table in a few boreholes on the north side of the site [MG-1425 (MW-1), MG-1426 (MW-2), and MG-1432 (T-6)], indicating that perched water may be present locally.

WATER-LEVEL MEASUREMENTS

Fluctuations

The principal changes in water levels are seasonal. Water levels generally start to decline in March or April and continue to decline until late fall. Even though precipitation is greater during the summer than during the winter, less precipitation reaches the water table during the summer and fall because large amounts of water are evaporated from the soil and transpired by vegetation. Rain and snowmelt recharge the aquifer during the winter and early spring, and water levels generally rise during this period. Hydrographs for 11 wells are shown in figures 15, 16, and 17. Natural annual fluctuations of water levels in these wells ranged from 11.4 to 28.3 ft. Water levels in the two wells (MG-1430 and MG-1431) with the highest water levels had the greatest annual fluctuations.

Seven of the 11 wells have very similar water-level hydrographs (figs. 15, 17), suggesting that areas near these wells have similar hydraulic properties. The four southernmost wells on the site (MG-1430, MG-1431, MG-1433, and MG-1434) (fig. 2) show rises in water levels after precipitation much sooner and have higher water levels than the other seven wells.

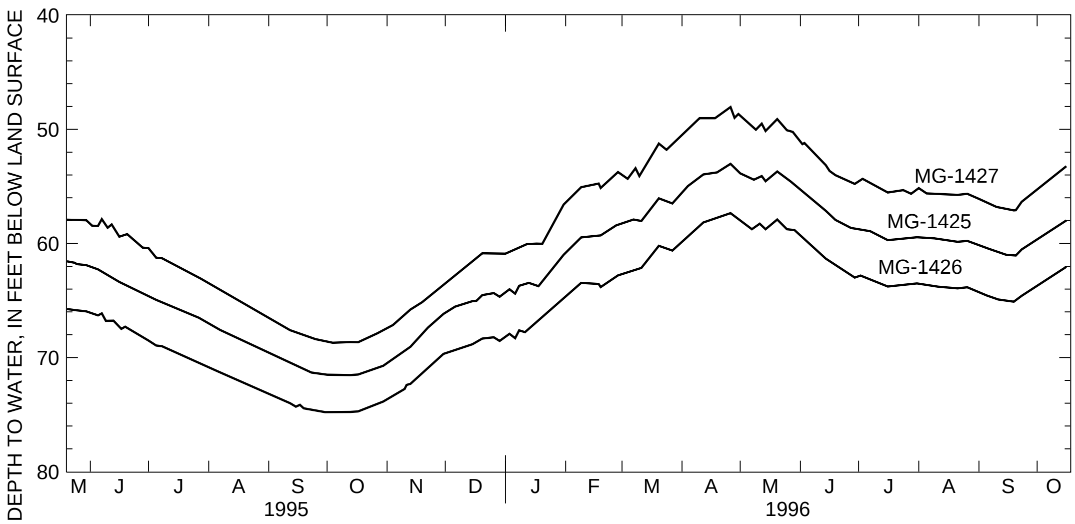

Figure 15. Hydrographs of wells MG-1425, MG-1426, and MG-1427, North Penn Area 12 Superfund Site, Worcester Township, Montgomery County, Pa., May 1995 to October 1996.

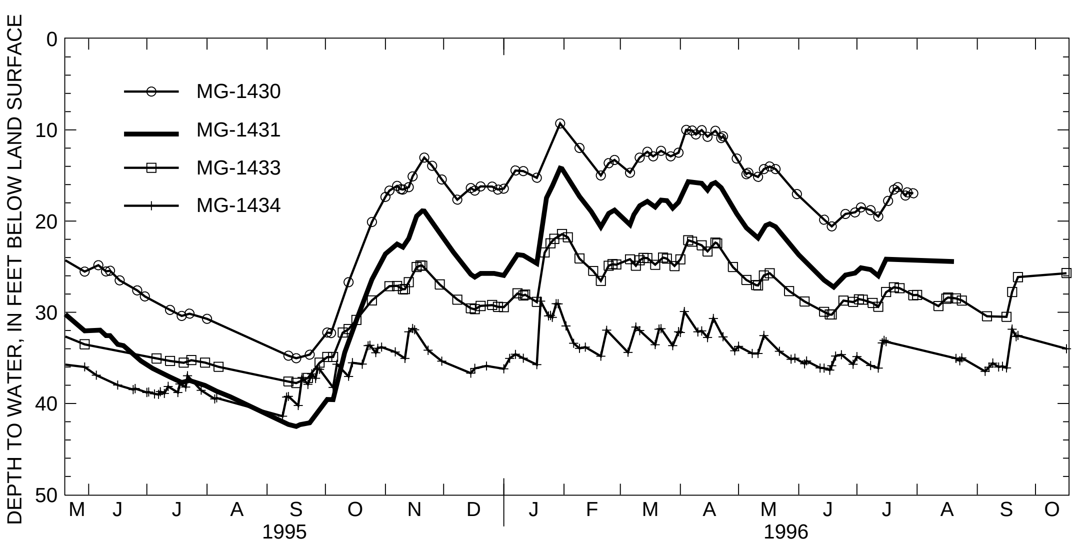

Figure 16. Hydrographs of wells MG-1430, MG-1431, MG-1433, and MG-1434, North Penn Area 12 Superfund Site, Worcester Township, Montgomery County, Pa., May 1995 to October 1996.

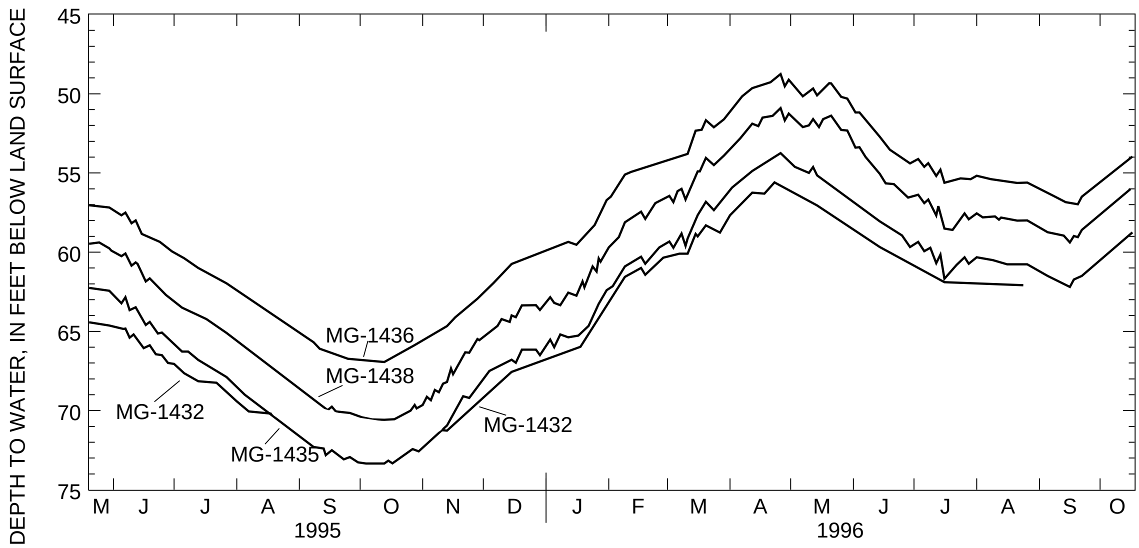

Figure 17. Hydrographs of wells MG-1432, MG-1435, MG-1436, and MG-1438, North Penn Area 12 Superfund Site, Worcester Township, Montgomery County, Pa., May 1995 to October 1996.

Wells MG-1428 and MG-1429 (figs. 18 and 19) show daily fluctuations that are caused by pumping of the Center Point Training Center production well (MG-1439). Pumpage is much less on weekends than on weekdays. Thus, fluctuations are much smaller on weekends. Water-level fluctuations caused by pumping the production well are greater in well MG-1428 than in well MG-1429 because well MG-1428 is closer to the production well than MG-1429.

Potentiometric-Surface Map

The approximate direction of ground-water flow (and possible contaminant movement) can be determined from potentiometric-surface maps. A map was prepared for the North Penn Area 12 Superfund Site and vicinity on the basis of measurements in late July 1995 (pl. 1). Water-level elevations were determined by subtracting the depth to water below land surface from land-surface elevations that were determined by leveling for on-site wells and by interpolating from 7-1/2-minute topographic maps for off-site wells. The map was prepared for a period of relatively low water level. The configuration of the potentiometric contour lines on the map indicates that ground water could flow radially away from the site. Because flow moves mostly along strike and down dip in the Triassic sediments, however, significant flow to the south is unlikely.

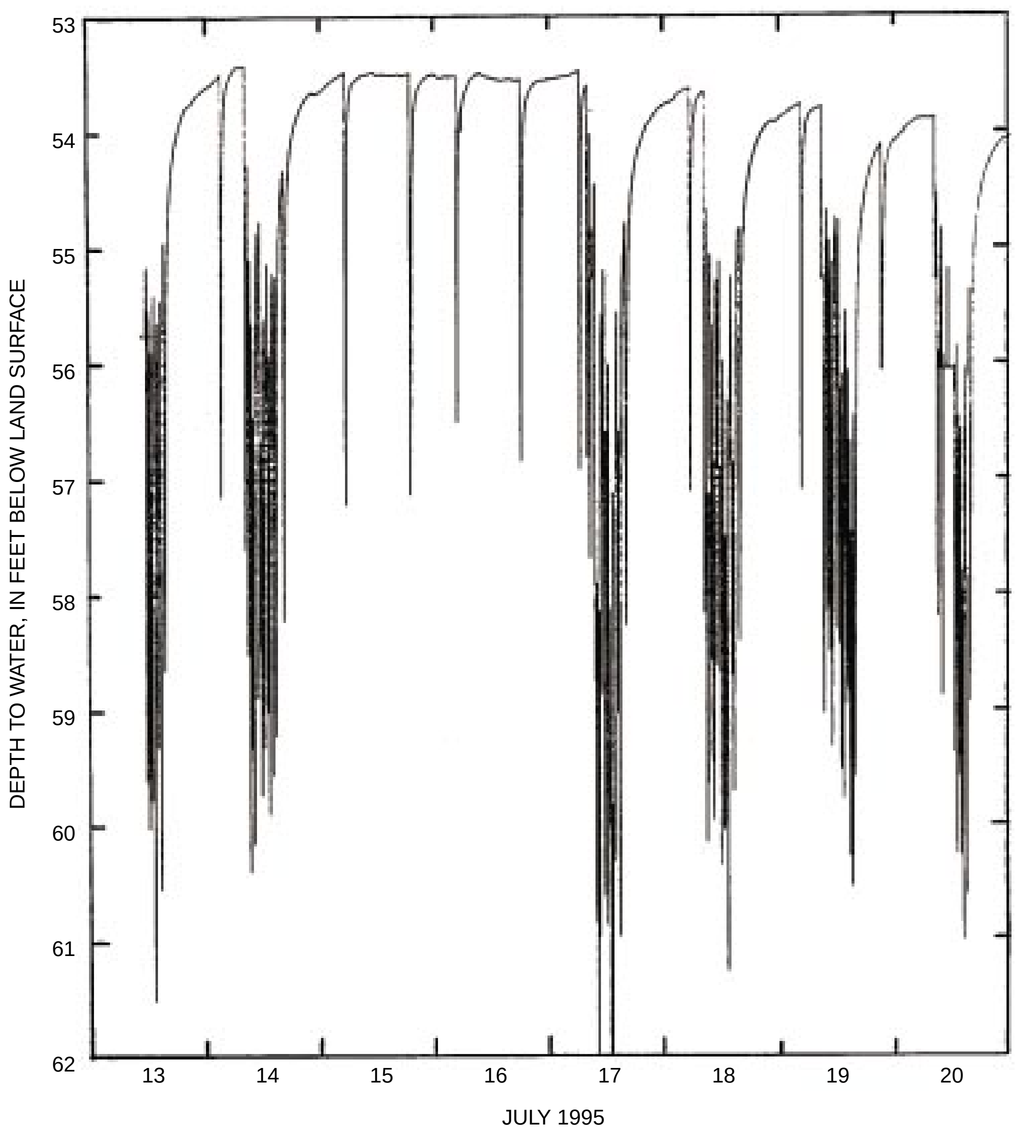

Figure 18. Hydrograph of well MG-1428, North Penn Area 12 Superfund Site, Worcester Township, Montgomery County, Pa., July 13-20, 1995.

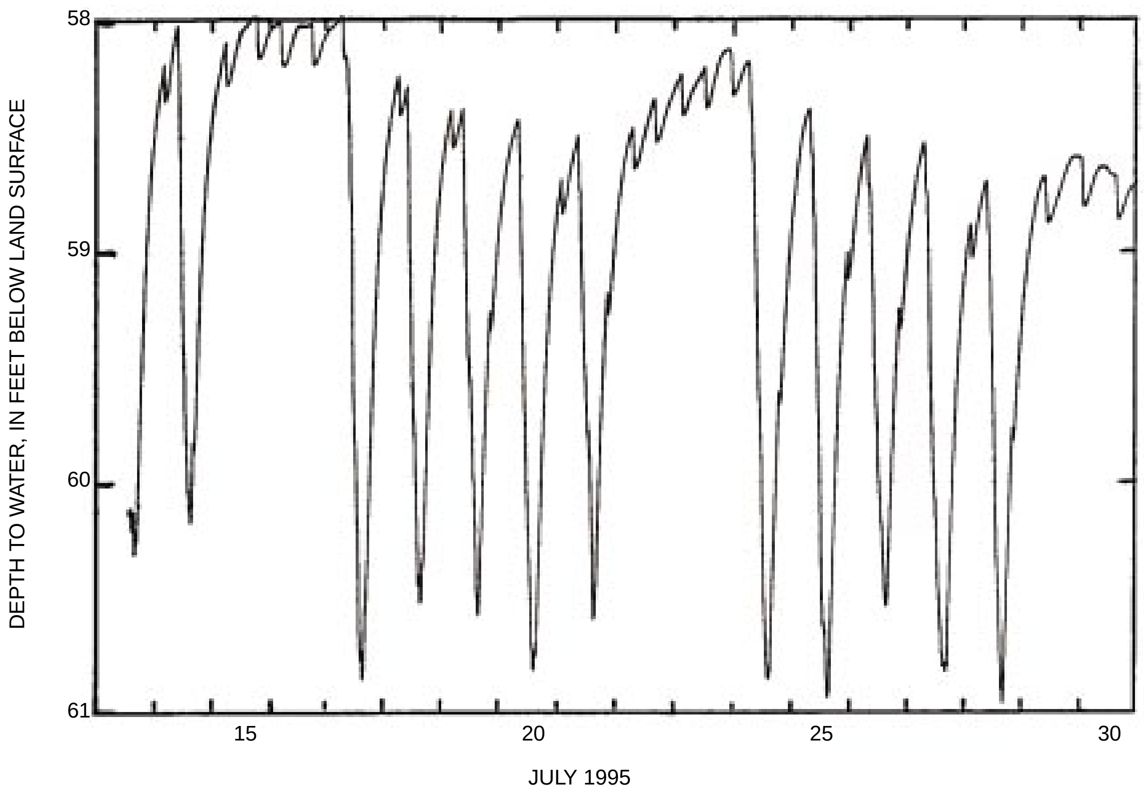

Figure 19. Hydrograph of well MG-1429, North Penn Area 12 Superfund Site, Worcester Township, Montgomery County, Pa., July 13-30, 1995.

SUMMARY

In order to remediate the North Penn Area 12 Superfund Site in Worcester Township, Montgomery County, Pa., the USEPA needs information on the hydrologic, geologic, and hydraulic characteristics of the site. The USGS, in cooperation with the USEPA, conducted a hydrogeological assessment of the site and the surrounding area. The data collected by the USGS in 1995 and 1996 will be used to help define the geology, distribution of fractures in the rocks, directions of ground-water flow, and probable patterns of contaminant migration at and in the immediate vicinity of the site.

The site is underlain by the Triassic-age Lockatong Formation that consists of interbedded gray to black siltstone and shale. The site is on a hilltop, indicating that these rocks are relatively resistant to erosion. A reddish-brown sandy siltstone unit has been mapped along the southeast border of the site. Generally, the beds strike N64°E and dip 10° to 20° to the northwest in the vicinity of the site. Ground water moves through fractures in the rock that are nearly vertical and horizontal. Permeability and storage typically are very low. Ground water in the upper part of the aquifer commonly is under unconfined (water-table) conditions and ground water in deeper parts of the aquifer is under confined or partially confined conditions.

Geophysical logs were obtained from eight wells ranging in depth from about 110 to 900 ft. The logs included caliper, natural-gamma, electromagnetic induction, single-point resistance, fluid resistivity, and fluid temperature. In addition, measurements of borehole flow were made with a heat-pulse flowmeter in eight wells. Data from the logs were used to identify the location of water-bearing fractures and intervals of borehole flow. Borehole television logs showed that most fractures were near vertical. Most fractures were at depths less than 100 ft. The fluid resistivity usually was higher in shallow zones than in deeper intervals, suggesting that the ground-water system is more active in the shallow zones. Under ambient conditions, little to no borehole flow was detected in wells MG-1425, MG-1426, MG-1427, MG-1429, and MG-1432 on the northwest side of the site and downward borehole flow of up to about 2 gal / min was measured in wells MG-1431 and MG-1432 on the southeast side of the site. Ground-water seepage occurred above the water table in several wells on the north side of the site.

Specific capacity ranged from 0.25 to 2.5 (gal / min) / ft for three open-hole wells MG-1425, MG-1426, and MG-1432. The specific capacity of fracture intervals isolated by packers ranged from 0.08 to 5.8 (gal / min) / ft; specific capacities were greater in well MG-1431 on the southeast side of the site than in well MG-1426 on the northwest side of the site. Significant drawdown in intervals adjacent to the isolated interval was measured in aquifer-isolation tests in wells on the northwest side of the site, indicating hydraulic connection in the area outside of the borehole.

Water levels measured in 11 wells at the site for 16 months starting May 1995 showed that recharge was seasonal; the highest water levels were in April 1996. Natural annual fluctuations range from 11.4 to 28.3 ft. Depth to water was greatest during September and October and was greater in wells on the north side of the site (maximum of 75 ft) than in wells on the south side of the site (maximum of 41 ft). Seven wells on the north side of the site had similar hydrographs. Hydrographs for four wells on the southeast side showed rises in water levels after precipitation much sooner than the other seven wells. Some wells showed daily fluctuations caused by pumping of a nearby production well. A map of water levels measured in wells at the site and in the vicinity during July 1995 shows that the water-level surface is roughly similar to topography; the highest levels are along the southwest crest of the hill at the site.

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APPENDIX—Record of wells at and near the North Penn Area 12 Superfund Site, Worcester Township, Montgomery County, Pennsylvania

Well number: The sequence number that is assigned to identify the well. It is prefixed by a two-letter abbreviation of the county.

Driller license number: 0121, Allen H. Dorn, 0188, C.S. Garber & Sons, Inc.; 0462, Charles Lauman & Son; 0512, Miller Pump Service, Inc.; 0514, F.L. Bollinger & Sons; 1539, Sensing and Weaver Well Drilling.

Use of site: O, observation; U, unused; W, withdrawal.

Use of water: C, commercial; H, domestic; N, industrial; P, public supply; U, unused.

Topographic setting: H, hilltop; S, hillside.

Altitude of land surface is leveled for on-site wells and estimated from topographic maps for the off-site wells. Datum is National Geodetic Vertical Datum of 1929.

Water level is in feet below land surface

gal/min: gallons per minute

(gal/min)/ft: gallons per minute per foot

µS/cm: microsiemens per centimeter at 25 degrees Celsius

--: no data

***APPENDIX**—Record of wells at and near the North Penn Area 12 Superfund Site, Worcester Township, Montgomery County, Pennsylvania*

USGS well number	Location		Owner	Driller license number	Year drilled	Primary		Elevation of land surface	Topo-graphic setting
	Latitude (degrees)	Longitude (degrees)				Use of site	Use of water		
Mg-494	401055	0752100	U.S. Army	0188	1955	W	P	460	S
1425	401054	0752119	Transicoil	0188	1988	O	U	472	H
1426	401052	0752121	Transicoil	0188	1988	O	U	467	H
1427	401057	0752113	Transicoil	0188	1988	O	U	463	H
1428	401057	0752100	Transicoil	0188	1988	O	U	457	H
1429	401100	0752104	Transicoil	0188	1988	O	U	462	H
1430	401047	0752104	Transicoil	0512	1976	U	N	443	S
1431	401050	0752105	Transicoil	0512	1976	U	N	450	S
1432	401054	0752113	Transicoil	0512	1976	U	N	470	H
1433	401050	0752108	Transicoil	0514	1990	O	U	458	H
1434	401050	0752117	Transicoil	0514	1990	O	U	474	H
1435	401053	0752131	Transicoil	0514	1990	O	U	462	S
1436	401053	0752131	Transicoil	0514	1990	O	U	461	S
1437	401058	0752120	Transicoil	0514	1990	O	U	459	S
1438	401058	0752120	Transicoil	0514	1990	O	U	459	S
1439	401058	0752059	Center Point Training Center	--	--	W	C	460	H
1512	401125	0752126	--	--	--	W	H	337	S
1513	401129	0752124	--	--	--	W	H	311	S
1514	401109	0752116	Philadelphia Variety Club	--	--	U	C	411	S
1515	401042	0752134	Posen, Greg	1539	1995	W	H	475	H
1516	401044	0752137	Posen, John	--	--	W	H	467	S
1517	401138	0752047	Lacek, Walter	--	--	W	H	298	S
1518	401126	0752042	Rock, Ann	--	--	W	H	345	S
1519	401118	0752033	Taaffe	--	--	W	H	406	S
1520	401037	0752115	Tyler, Jack	--	--	W	H	435	S
1521	401101	0752158	Walker, Mary	--	--	W	H	345	S
1522	401109	0752052	Carney, Dennis	0512	1986	U	H	419	S
1523	401105	0752050	Carney, Dennis	0512	1986	U	H	424	S
1524	401107	0752046	Carney, Dennis	0512	1986	W	H	409	S
1525	401129	0752113	Cifelli, Joe	0462	1989	W	H	316	S
1526	401126	0752128	Clee, Shawn	0512	--	W	H	329	S
1527	401123	0752101	Benner, Gregory	0512	--	W	H	360	S
1528	401110	0752037	Fegley, Len	0121	--	W	H	408	S
1529	401113	0752052	Larson, Linda	--	--	W	H	407	S
1530	401056	0752136	Brown, Bob	--	--	W	H	428	S
1531	401101	0752135	Tevner, Berg	--	--	W	H	403	S
1532	401104	0752133	Schultz, Richard	--	--	W	H	412	S

APPENDIX—*Record of wells at and near the North Penn Area 12 Superfund Site, Worcester Township, Montgomery County, Pennsylvania*—*Continued*

Depth of well (feet)	Casing		Depth of water-bearing zone(s) (feet)	Water level (feet)	Date water level measured	Reported yield (gal/min)	Measured yield			Field water quality	
	Depth (feet)	Diameter (inches)					Specific capacity [(gal/min)/ft]	Discharge (gal/min)	Pumping period (hours)	Date measured	Specific conductance (µS/cm at 25°C)
230	40	--	--	51.00	07-24-57	23	0.23	23	24	--	--
122	23	6	96	61.70	02-24-95	--	.07	3	.5	03-07-95	658
110	26	6	90	66.00	02-24-95	--	.03	1	.5	03-16-95	414
160	23	6	89	57.70	02-23-95	--	.05	<1	.5	--	--
110	36	6	90	47.00	02-25-95	--	.11	2	.5	03-13-95	393
160	33	6	113	47.50	04-12-96	--	.01	<1	--	03-16-95	391
304	45	6	--	17.80	02-26-95	36	--	--	--	03-13-95	412
133	45	6	--	24.50	02-25-95	45	--	--	--	03-13-95	10
913	21	6	--	63.80	02-21-95	--	--	--	--	03-09-95	579
95	75	4	75	22.80	04-12-96	2	--	--	--	03-14-95	471
72	52	4	52	38.30	07-27-95	2	--	--	--	03-07-95	364
125	105	4	105	68.20	07-27-95	1	--	--	--	03-15-95	460
150	136	8	136	62.00	07-27-95	--	--	--	--	03-15-95	352
107	21	8	87/91	63.60	07-27-95	<1	--	--	--	--	--
200	117	8	193	61.60	02-22-95	<1	--	--	--	--	--
498	29	8	--	48.60	02-25-95	--	--	--	--	03-08-95	436
--	--	--	--	64.00	07-21-95	--	--	--	--	--	--
--	--	--	--	41.00	07-21-95	--	--	--	--	--	--
--	--	--	--	60.10	07-27-95	--	--	--	--	--	--
400	40	6	--	68.60	07-20-95	--	--	--	--	--	--
149	--	--	--	62.60	07-20-95	--	--	--	--	--	--
--	--	--	--	35.60	07-20-95	--	--	--	--	--	--
355	--	--	--	83.80	07-20-95	--	--	--	--	--	--
--	--	--	--	111.00	07-20-95	--	--	--	--	--	--
--	--	--	--	53.30	07-21-95	--	--	--	--	--	--
92	--	--	--	29.60	07-21-95	30	--	--	--	--	--
350	21	6	45	22.90	07-21-95	<1	--	--	--	--	--
500	21	6	--	16.10	07-21-95	<1	--	--	--	--	--
725	20	6	50	36.50	07-21-95	<1	--	--	.5	--	--
300	--	--	--	54.80	07-21-95	--	--	--	--	--	--
440	--	--	--	52.80	07-21-95	6	--	--	--	--	--
145	--	--	--	47.80	07-24-95	21	--	--	--	--	--
234	--	--	--	22.80	07-24-95	34	--	--	--	--	--
500	--	--	--	62.60	07-24-95	<1	--	--	--	--	--
195	--	--	--	44.30	07-27-95	20	--	--	--	--	--
215	--	--	--	54.40	07-27-95	--	--	--	--	--	--
180	--	--	--	61.10	07-27-95	--	--	--	--	--	--